



BNL-71445-2003

LEACHING OF SLAG FROM STEEL RECYCLING: RADIONUCLIDES AND STABLE ELEMENTS

DATA REPORT

January 15, 1997/ Revised September 9, 1997

Mark Fuhrmann
Brookhaven National Laboratory
PO Box 5000, Upton, NY 11973-5000
(631) 344-2224, fuhrmann@bnl.gov

Martin Schoonen
Department of Earth Sciences
State University of New York at Stony Brook

**Brookhaven National Laboratory
Upton, New York 11973-5000**



BNL-71445-2003

LEACHING OF SLAG FROM STEEL RECYCLING: RADIONUCLIDES AND STABLE ELEMENTS

DATA REPORT

January 15, 1997/ Revised September 9, 1997

Mark Fuhrmann
Brookhaven National Laboratory
PO Box 5000, Upton, NY 11973-5000
(631) 344-2224, fuhrmann@bnl.gov

Martin Schoonen
Department of Earth Sciences
State University of New York at Stony Brook

**Environmental Research and Technology Division
Environmental Sciences Department**

Brookhaven National Laboratory
P.O. Box 5000
Upton, NY 11973-5000
www.bnl.gov

Managed by
Brookhaven Science Associates, LLC
for the United States Department of Energy under
Contract No. DE-AC02-98CH10886

*This work was performed under the auspices of the U.S. Department of Energy.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of author's expresses herein do not necessarily state to reflect those of the United States Government or any agency thereof.



INTRODUCTION

Of primary importance to this study are releases of radionuclides from slags. However, releases of other constituents also provide valuable information on releases of elements that may be toxic (e.g. Cr) or that may be used as analogs for radionuclides (e.g. K for Cs). In addition, leaching of bulk constituents from the slag gives information on weathering rates of the bulk material that can be used to estimate releases of non-leachable elements. Consequently, we have examined leaching of

- radionuclides from those slags that contain them,
- bulk elemental constituents of the slags,
- anionic constituents
- trace elements, through spot checks of concentrations in leachates.

Analysis by ICP of elemental constituents in leachates from radioactive samples was limited to those leachate samples that contained no detectable radionuclides, to avoid contamination of the ICP.

In this data report we present leaching results for five slags that were produced by recycling steel. Two of the slags were generated at facilities that treat radioactively contaminated scrap, consequently the slag contains radionuclides. The slag from the other three was not contaminated. Because **of** this, we were able to examine the chemical composition of the slag and of the leachate generated during tests of these slags. For these materials we believe that leach rates of the stable elements can be used **as** analogs for radionuclides if the same steel processing method were used for radioactive material.

Slags were obtained by personnel at Jack Faucett and Associates, from 5 facilities:

Carolina Metals in Barnwell, South Carolina, (Samples = CM)

SEG in *Oak* Ridge Tennessee, (Samples = SEG)

Heckett Multiserve, Provo, Utah (slag from Geneva Steel) (Samples = Q-BOP)

Ameristeel, Knoxville, Tennessee, and (Samples = AS)

Steel Slag Coalition, Washington ,D.C. (Samples = E)

The first two listed above were radioactively contaminated slags. Each company sent three samples of slag.

METHODS

The objective of this project is to examine the leachability of a set of slags, to determine if there is a significant hazard presented by releases from radioactive slags that are disposed **of**. Two types of leach tests were used. The Accelerated Leach Test (ALT) (ASTM C-1308-95) and a flow-through column test. The ALT is a semi-static leach test in which the leachate is replaced periodically over a period of 11 days. It is used to determine leach rates of waste materials and to test if diffusion controls releases from materials. It has associated with it a computer code that examines the data generated in the test against a set of release models (diffusion and dissolution).

Flow through tests are thought to be more realistic than a semi-static test and to represent flow through a deposit of a granular waste.

Accelerated Leach Test

Subsamples of each slag (15 in total) were tested at 20°C and at 60°C. The leachant was distilled/deionized water. Because one of the slags was only supplied as a powder, some tests were conducted with the pulverized slag loaded in dialysis membrane (Spectra/Por #2, 12,000-14,000 Daltons). Other slags were supplied as monolithic pieces. Consequently, two sets of experiments were conducted for one of the slags; pulverized subsamples were leached in the dialysis membrane and other subsamples were leached as monoliths. This test will allow correlation of releases from the two different forms. Most tests (all of the radioactive samples) were conducted on monoliths. For the membrane experiments, 200 mL of water were used at each sampling interval. The monoliths were leached in 300 mL because the slag pieces required a greater depth of water to be covered. As per the test method, the leachate was not filtered prior to analysis.

Flow-Through Tests

To investigate leaching under dynamic flow conditions, experiments were set-up using plexiglass columns, 7.3 cm in length with inside diameters of 3.2 cm. For the slag from Carolina Metals a column 6.3 cm long and 1.5 cm in diameter was used because of the amount of granular material available. The column was mounted vertically, with the inlet at the bottom. Distilled water was pumped through the column with a low-speed peristaltic pump (Gilson, Minipuls 2). Flow velocities were maintained that were similar to groundwater flow within an aquifer (~60 mL/day). Effluent was initially collected daily, and then at longer intervals. Pre-weighed polyethylene bottles were used for sampling, which were subsequently re-weighed to determine daily flow rates. Aliquots of these samples were taken for analysis. Figure 1 shows the apparatus for the flow-through column experiment.

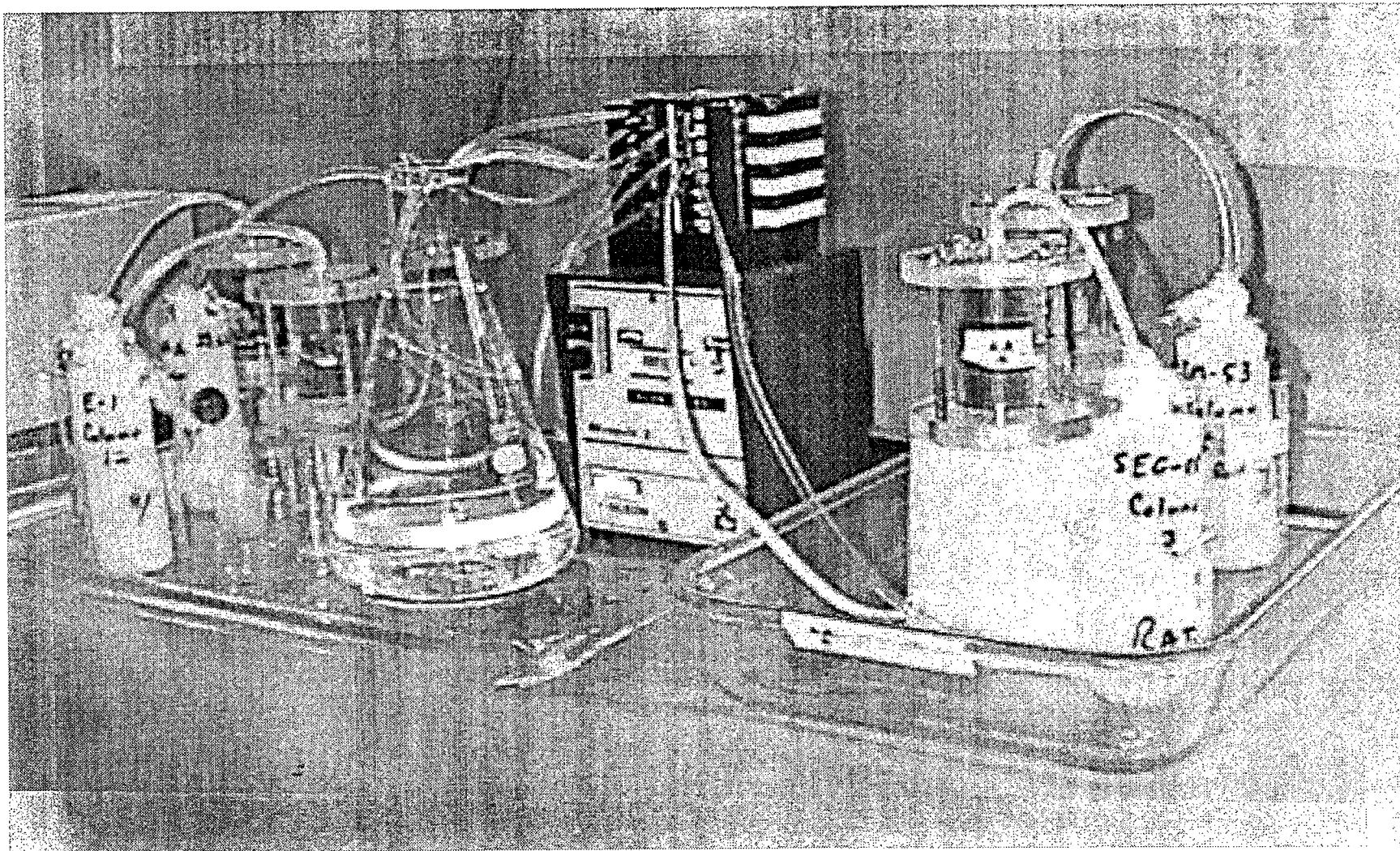


Figure 1. Apparatus for the flow through experiments, showing the columns, pump and water reservoirs.

Leachate Analysis

Leachates from the non-radioactive slags were analyzed for Ca, Si, Al, Fe, Mn, Zn, Sr, and Na by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP). Spot checks were made for B, U, Nd, Ce, V and Mo; none was observed. ICP analysis was conducted with reagent and instrument blanks, standards and calibration checks from a source different than the standards. Samples were acidified with 50% Ultrex HNO₃. A standard and a blank were run every 10 samples.

Leachates were also analyzed by Ion Chromatography (Dionex) for SO₄²⁻, Cl⁻, and F⁻. Standards were made from reagent grade salts and were run every 7 samples. An interference was observed with F⁻ analysis when Al concentrations were greater than about 20 mg/L in the leachate. Hence, in Al-rich samples, the F⁻ concentration is depressed.

Leachate samples from the radioactive slags were analyzed in two ways. First, spot checks were made by counting 20-30 mL of leachate on an intrinsic Ge gamma-spectrometer (with a Canberra computer system). Count times ranged from 1000 to 2000 minutes. Only very low (if any) counts were observed in most samples. Because of the low count rates for gamma-spectroscopy, all samples were analyzed by Liquid Scintillation. Three mL of leachate were mixed with 15 mL of Ultima Gold XR scintillation cocktail and each sample was counted for 10 minutes on a Packard Liquid Scintillation System (Model 1900 TR). Distilled water blanks were run at the same time. Windows were set at 0-18.6 keV, 18.6-156 keV and 156-2000 keV.

Source Terms of Slags

Each non-radioactive slag was subsampled and sent to Activation Laboratories LTD in Ancaster, Ontario. A standard, of a composition unknown to the company, was included in the set of samples. Analysis was done by neutron activation and by digestion and ICP, giving data for about 60 elements. Comparison of results of the standard analysis with known quantities in the standard were acceptable.

The radioactive slags could not be submitted for this type of analysis because of the quantity of radionuclides present in them. Each sample, prior to leaching was analyzed by gamma spectroscopy. These pieces of slag were irregularly shaped, they did not conform to our standard geometries. But it was necessary to analyze each specific piece of slag that was to be leached in order to minimize intersample variability. Because of this, determination of radionuclide concentration is probably not better than +/- 20%.

RESULTS

Source Terms

There are two data sets for the source terms; the elemental data and the radionuclide data. The elemental source terms for the major elements are presented in Table 1. The compositions of the non-radioactive slags were dominated by Ca, Fe, **Si**, Mg and Al. Sr was present at concentrations from **184 - 308 ppm**.

Source terms for the radioactive samples are contained in Table 2. The radioactive slags contained ^{134}Cs , ^{137}Cs , ^{60}Co , ^{54}Mn , and daughter isotopes of the ^{238}U decay chain, specifically, ^{234}Th , ^{214}Pb and $^{226}\text{Ra}/^{235}\text{U}$ (185 keV). Not all samples contained all radionuclides. Because of the geometry issue, only ^{137}Cs is given in terms of both counts per minute/gram (cpm/g) and in pCi/g as an example of the approximate activity levels.

The slags that were obtained for this project were of two types. Those obtained from the radioactive waste treatment facilities were produced with small quantities of slag producing additives and at temperatures around 2800° F. In contrast, at least two of the non-radioactive slags were produced with lime/dolomite added and at about 2000° F. This results in two very different slags. Those produced with lime/dolomite are light in color, friable and vesicular. The radioactive slags and one non-radioactive slag were dark gray to black, very hard, and basalt-like in appearance.

Radionuclide Leaching Data Analysis

For the radioactive slags, gamma-spectroscopy was done for one or two samples per ALT experiment, because of the long count times required. No activity was observed by gamma spectroscopy. Detection limits are approximately 0.13 pCi/g of ^{137}Cs . As a result, all samples were analyzed by Liquid Scintillation. Although this method does not provide radionuclide specific information, it is much more sensitive than gamma-spectroscopy and therefore gives information on total alpha/beta activity. Results are contained in the radionuclide directory of the data diskettes. As with the gamma-spectroscopy, radionuclide concentrations in the leachate were very low, **if at** all above background. Typical corrected values were no more than several cpm/g of leachate, although the first leaching interval often contains the most activity due to surface rinse-off. Activity detected by LSC was generally in the first channel, from **0-18.6 keV** implying that a low energy Beta is being detected.

Table 1
Major Constituents of Non-radioactive Slags

SAMPLE	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	LOI	TOTAL,	Ba	Sr
	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm
E-1	11.89	14.6	10.94	0.8	11.67	41.52	0.08	0.03	1.49	0.07	-0.92	92.17	305	231
E-2	10.09	5.1	28.96	2.93	6.09	41.71	0.03	<0.01	0.38	0.34	-2.13	93.51	286	184
E-3	10.83	5.37	27.73	3.02	5.59	39.59	0.03	<0.01	0.46	0.32	0.32	93.23	346	189
AS001	19.07	10.49	19.99	6.77	5.24	34.88	0.08	0.04	0.44	0.36	-3.36	93.99	1183	308
AS002	16.34	8.63	17.75	4.18	11.11	37.84	0.06	0.01	0.38	0.5	-2.89	93.9	1345	248
AS003	17.67	8.88	15.57	4.58	10.97	39.19	0.04	<0.01	0.44	0.35	-2.46	95.2	1010	300
Q-BOPA	15.29	1.22	25.24	2.21	8.67	41.6	0.02	0.04	0.26	0.68	-1.62	93.6	28	191
Q-BOPB	14.89	1.16	25.36	2.19	8.31	41.43	<0.01	<0.01	0.26	0.68	-0.1	94.2	25	188
Q-BOPC	18.28	2.04	22.45	1.95	8.85	40.56	0.1	0.09	0.26	0.62	-0.51	94.68	82	227
BNLSTD	66.5	17.36	8.12	0.05	1.49	0.71	0.19	4.12	1.05	0.08	1.3	100.95	642	68

Table 2**Source Terms of Radionuclides in Slag Samples Used for Leaching Experiments**

Source	Sample	Experiment &	sample	Count	U-238 chain										Mn-54	Ag-108
					Cs-137	Cs-137	Co-60	Th-234	Th-234	U235, Ra226	Cs-134	Cs-134	Mn-54	Ag-108		
					Temp	Wt g	Time min	cpm/g	pCi/g	cpm/g	91 cpm/g	63 cpm/g	185 cpm/g	cpm/g	cpm/g	cpm/g
CM	57	20 C ALT	70.51	30	4.6	153	0.5	1.2	0.6	0.5	0.6	0.4	0.5	0.5	0.0	
CM	53	20 C ALT	22.45	3	445.3	14700	-0.1	0.3	-0.1	-0.5	145.8	89.3	13.2	1.0		
CM	55	20 C ALT	63.05	36	9.0	298	0.9	0.1	0.0	0.0	1.0	0.7	1.6	-0.0		
SEG	986-900-190	20 C ALT	32.29	100	1.5	50	0.8	1.7	1.0	0.4	0.1	0.1	1.1	0.2		
SEG	96-8000-000A	20 C ALT	23.06	60	4.1	135	0.4	2.5	1.7	0.3	0.3	0.2	2.4	-0.0		
SEG	96-8000-000B	20 C ALT	13.69	15	16.6	550	1.0	9.8	5.5	1.9	1.1	0.7	10.0	0.1		
CM	53	60 C ALT	41.87	2	250.7	8290	-0.1	0.5	-1.0	0.3	78.0	49.0	9.3	-0.3		
CM	57	60 C ALT	50.4	6	7.9	261	0.1	1.0	0.5	0.3	0.8	0.5	0.7	-0.1		
CM	55	60 C ALT	64.79	15	11.4	376	0.8	0.0	0.0	0.0	1.1	0.6	1.6	-0.0		
SEG	96-8000-000B	60 C ALT	42.53	15	4.9	163	0.6	3.1	1.8	0.5	0.3	0.2	3.0	-0.0		
SEG	96-8000-000A	60 C ALT	24.44	30	0.8	26	2.5	0.6	0.3	0.1	0.0	0.0	0.5	0.0		
SEG	986-900-190	60 C ALT	34.75	500	1.4	46	0.7	1.0	0.6	0.3	0.1	0.1	0.9	0.1		
CM	53	COLUMN	15	2	1184.9	39200	5.3	2.3	2.0	6.2	354.3	241.9	49.3	1.5		
SEG	96-009855	COLUMN	10.56	10.29	22.9	757	78.1	11.2	7.5	1.8	1.1	1.4	0.8	74.2		

Radionuclide Leaching/ Accelerated Leach Test

Count rates obtained by Liquid Scintillation analysis of the leachate from the Accelerated Leach Tests are shown in Table 3 for 20° C tests and in Table 4 for those tests conducted at 60° C. Several of the samples show essentially no activity in the leachate. Others have low count rates of an unidentified low-energy (<18.6 keV) beta emitter. Typically the first sampling interval had higher count rates, presumably due to rinse off, than the remainder of the test intervals. Count rates per interval are plotted in Figures 2 and 3 for leaching results by LSC at 20° and 60° C respectively. Count rates at 60° C were not elevated compared to those at 20° C. With the exception of 4 samples out of more than 160, all LSC count rates were below 20 cpm/g. These results have blanks subtracted from them., but many of these samples may represent background activities.

Spot checks of ALT leachate by gamma spectroscopy indicated no releases to the leachate. This is not surprising since detection limits of LSC are significantly lower than those of gamma spectroscopy. By determining a detection limit of the gamma spectroscopy, and knowing the quantity of various gamma emitters in the slag, a maximum leach rate can be calculated. These rates as fractional releases per day are shown in Table 5a and 5b, for experiments at 20° and 60°C respectively, for those gamma emitters observed in the slag samples. These rates are based on an acceptable peak of 50 counts in 1000 minutes, counting sample of 25 mL and total leachate volume of 300 mL. From this a DL of 0.6 cpm was calculated. Consequently the calculated maximum leach rate, at the DL is a function of the source term. The rates presented in Tables 5a and 5b are maximum release rates. It is not strictly possible to take this approach for calculating a release rate with detection limits for the LSC measurements, because no source term is available by LSC. However, the efficiency of LSC is between 50 and 100 times greater than that of gamma-spectroscopy. Thus leach rates can be taken to be as much as two orders of magnitude lower than shown in the tables.

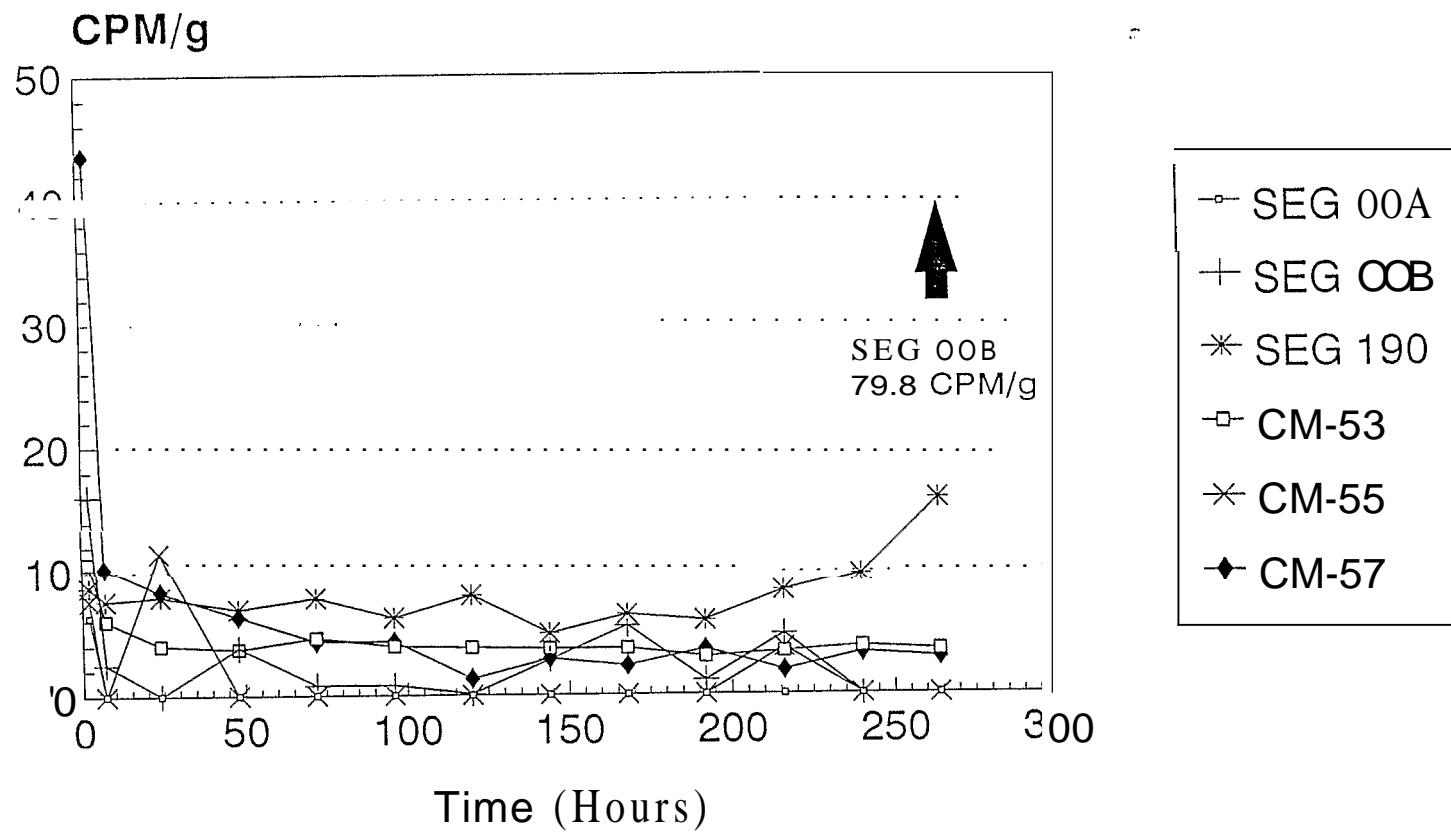


Figure 2. Liquid Scintillation data for leachate from the Accelerated Leach Test at 20° C. All counts were found in the low energy channel (0-**18.6 keV**).

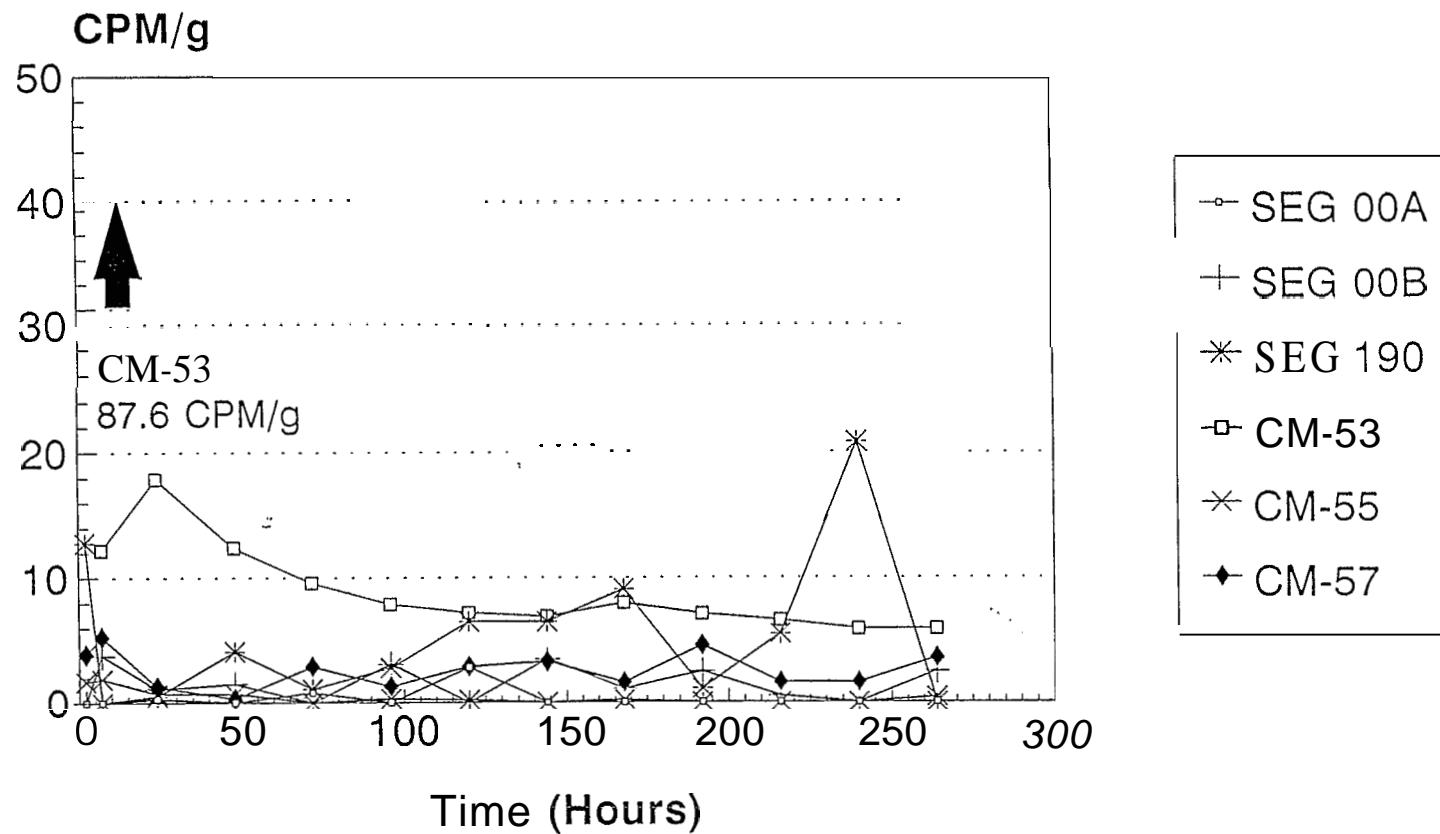


Figure 3. Liquid Scintillation data for leachate from the Accelerated Leach Test at 60° C. All counts were found in the low energy channel (0-18.6 keV).

Table 3.
Data from Liquid Scintillation Counting
Accelerated Leach Test at 20° C

		SEG 00A	SEG 00B	SEG 190
Interval	cpm/g	cpm/g	cpm/g	
1	6.3	16.1	8.7	
2	0.0	2.5	7.6	
3	-0.2	-0.2	7.9	
4	-0.2	3.8	6.9	
5	-0.2	0.8	7.8	
6	-0.2	0.8	6.2	
		0.1	8.0	
8	-0.2	2.8	4.9	
9	-0.2	5.5	6.4	
10	-0.2	1.1	5.9	
11	-0.2	4.8	8.3	
12	-0.2	-0.2	9.8	
13	-0.2	79.8	15.8	
Interval	CM-53	CM-55	CM-57	
	cpm/g	cpm/g	cpm/g	
1	10.7	7.6	43.6	
2	6.0	-0.2	10.3	
3	4.0	11.5	8.3	
4	3.7	-0.2	6.3	
5	4.6	-0.2	4.3	
6	3.9	-0.2	4.3	
	3.8	0.2		
	3.7	0.2	2.9	
	3.7	0.2	2.3	
10	3.0	-0.2	3.6	
11	3.4	3.7	1.9	
12	3.8	-0.2	3.3	
13	3.5	-0.2	2.9	

Table 4.
Data from Liquid Scintillation Counting
Accelerated Leach Test at 60° C

Interval	SEG 00A cpm/g	SEG 00B cpm/g	SEG 190 cpm/g
1	-0.2	-0.5	12.8
2	-0.2	3.8	-1.9
3	0.3	1.1	0.5
4	-0.2	1.5	4.1
5	0.8	-0.9	1.1
6	-0.2	3.1	2.8
7	2.8	-0.2	6.5
8	-0.2	3.5	6.5
9	-0.2	1.1	9.1
10	-0.1	2.5	1.1
11	-0.2	0.5	5.5
12	-0.2	-1.2	20.8
13	-0.2	2.5	-1.5
Interval	CM-53 cpm/g	CM-55 cpm/g	CM-57 cpm/g
1	87.6	1.7	3.9
2	12.2	1.9	5.3
3	17.9	0.7	1.3
4	12.4	0.7	0.3
5	9.6	0.0	2.9
6	7.9	0.3	1.3
7	7.2	0.2	2.9
8	6.9	-0.1	3.3
			1.6
10	7.1	-0.2	4.6
11	6.6	-0.2	1.6
12	5.9	-0.2	1.6
13	5.9	0.4	3.6

Table 5a
Radionuclide Release Rates (Fractional Release/Day)
20" C Slag Leaching Results, ALT Experiments
Maximum Release Rates Based on Detection Limits

Sample	Cs-137	Th-234	Cs-134	Mn-54	Ag-108	Co-60
CM-53	6×10^{-5}	8×10^{-2}	2×10^{-4}	2×10^{-3}	---	---
CM-55	1×10^{-3}	1×10^{-1}	9×10^{-3}	6×10^{-3}	---	1×10^{-2}
CM-57	2×10^{-3}	7×10^{-3}	1×10^{-2}	2×10^{-2}	---	2×10^{-2}
SEG-190	1×10^{-2}	1×10^{-2}	2×10^{-1}	2×10^{-2}	9×10^{-4}	2×10^{-2}
SEG-00A	6×10^{-3}	1×10^{-2}	9×10^{-2}	1×10^{-2}	---	7×10^{-2}
SEG-00B	3×10^{-3}	4×10^{-3}	4×10^{-2}	4×10^{-3}	---	4×10^{-2}

Table 5b.
Radionuclide Release Rates (Fractional Release/Day)
60" C Slag Leaching Results, ALT Experiments
Maximum Release Rates Based on Detection Limits

Sample	Cs-137	Th-234	Cs-134	Mn-54	Ag-108	Co-60
CM-53	6×10^{-5}	3×10^{-2}	2×10^{-4}	2×10^{-3}	---	---
CM-55	8×10^{-4}	2×10^{-1}	8×10^{-3}	6×10^{-3}	---	1×10^{-2}
CM-57	2×10^{-3}	1×10^{-2}	1×10^{-2}	2×10^{-2}	---	2×10^{-1}
SEG-190	1×10^{-2}	2×10^{-2}	2×10^{-1}	2×10^{-2}	2×10^{-4}	3×10^{-2}
SEG-00A	3×10^{-2}	4×10^{-2}	---	5×10^{-2}	---	1×10^{-2}
SEG-00B	3×10^{-2}	4×10^{-3}	5×10^{-2}	5×10^{-3}	---	2×10^{-2}

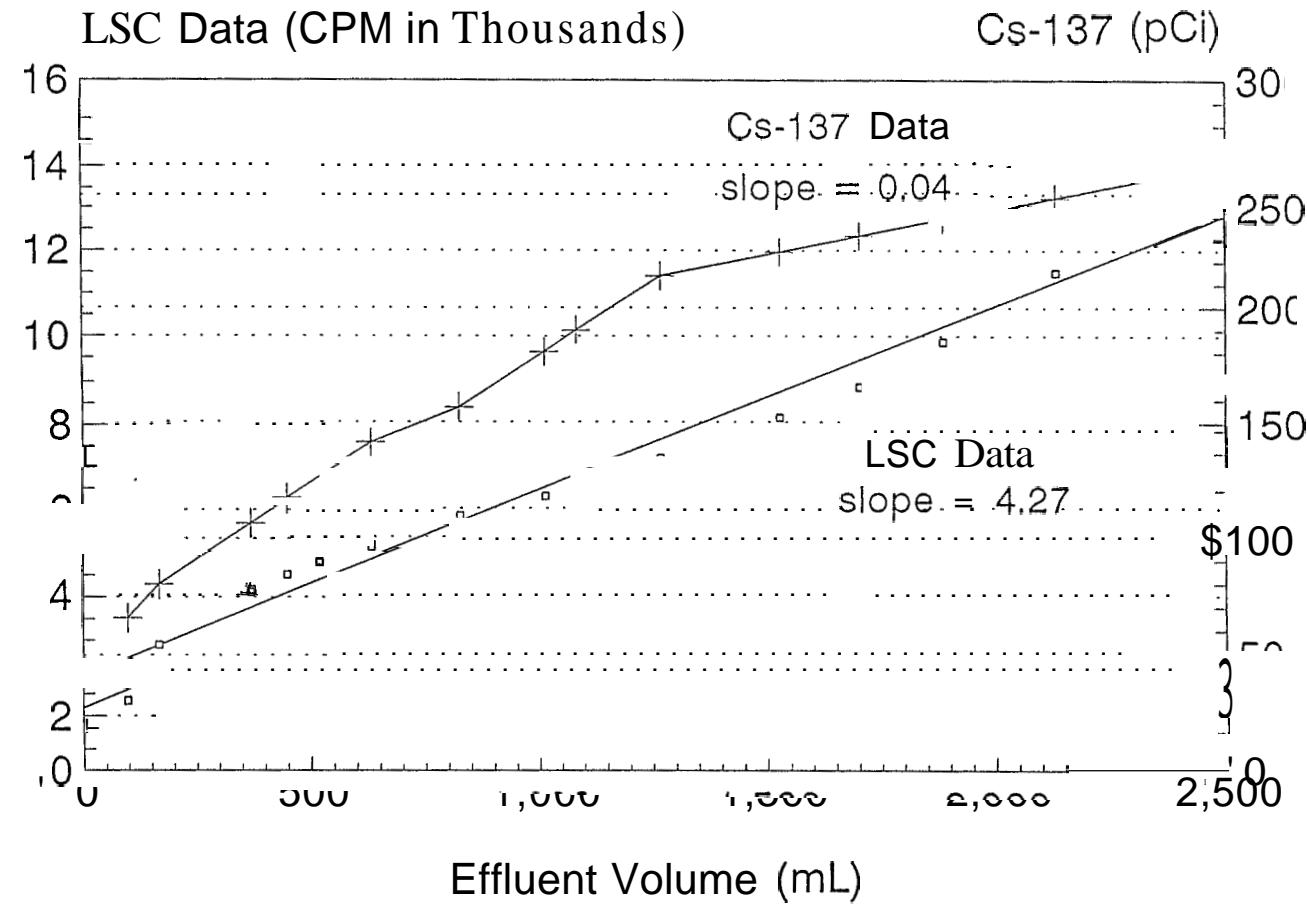


Figure 4. Cumulative releases of ^{137}Cs and LSC data in leachate from the SEG Slag in the Column Experiment

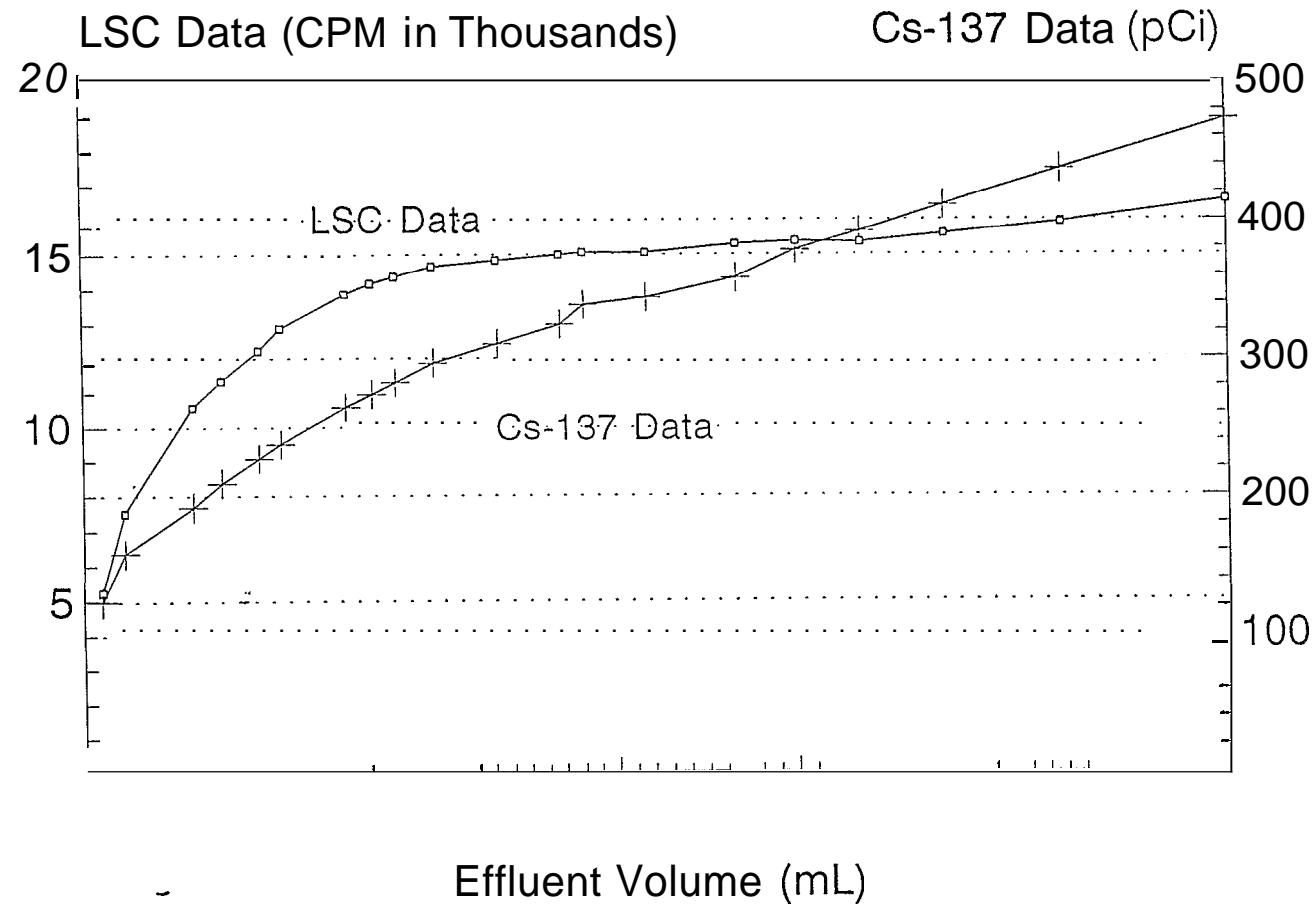


Figure 5. Cumulative releases of ^{137}Cs and LSC data in leachate from the CM Slag in the Column Experiment

Table 6.
Radionuclides in Leachate from the Column Experiment for SEG Slag

	Effluent Wt, g	LSC corr cpm/mL	LSC cpm released	Sum LSC cpm released	Cs-137 cpm/g	Co-60 cpm/g	Cs-137 pCi/g	Time Days	pH
SEG-Col-1	98.3	23.8	2343	2343	0.016	0.008	0.67	1.0	7.1
SEG-Col-2	68.9	8.0	552	2895	0.005	<0.001	0.21	2.1	7.55
SEG-Col-3	202.3	6.0	1214	4108	0.003	<0.001	0.13	5.2	7.7
SEG-Col-4	79.4	5.0	394	4503	0.003	<0.001	0.13	6.5	
SEG-Col-5	70.6	4.2	296	4799				7.6	
SEG-Col-6	113.2	3.1	355	5154				9.4	7.95
SEG-Col-7	193.2	3.5	670	5823	0.002	<0.001	0.08	12.4	
SEG-Col-8	186.9	2.4	455	6278	0.003	<0.001	0.13	15.3	
SEG-Col-9	71.6	2.8	200	6479				16.4	7.95
SEG-Col-10	183.4	3.6	660	7139				19.3	
SEG-Col-11	260.3	3.7	954	8093	<0.001	<0.001	<0.04	23.3	
SEG-Col-12	174.1	4.1	708	8801	<0.001	<0.001	<0.04	26.1	8.25
SEG-Col-13	184.1	5.8	1062	9863				28.9	
SEG-Col-14	245.1	6.6	1610	11473				32.8	
SEG-Col-15	338.6	6.8	2302	13775				38.1	8.15

Table 7.
Radionuclides in Leachate from the Column Experiment for the CM-53 Slag

		corrected LSC chA	Increment LSC cpm	Sum LSC cpm					
	Effluent Wt. g	LSC chA cpm/g	Released	Released	Cs-137 cpm/g	Cs-137 pCi/g	Cs-134 cpm/g	Time Days	pH
CM-53-1	49.00	106.97	5241	5241	0.061	2.54	0.014	0.8	
CM-53-2	63.80	35.50	2266	7507	0.013	0.54	0.011	1.8	
CM-53-3	193.4	15.90	3075	10582	0.004	0.17	<0.003	4.9	
CM-53-4	81.7	9.47	773	11355	0.005	0.21	<0.003	6.2	
CM-53-5	105.60	8.23	870	12224	0.004	0.17	<0.003	7.8	
CM-53-6	61.70	10.53	650	12874	0.004	0.17	<0.003	8.8	
CM-53-7	182.80	5.43	993	13867				11.7	
CM-53-8	72.40	4.07	295	14162	0.003	0.13	<0.003	12.9	8.02
CM-53-9	65.40	2.90	190	14351				13.9	8.1
CM-53-10	105.70	2.77	292	14644				15.6	
CM-53-11	180.50	0.97	174	14818	<0.003	<0.13	<0.003	18.4	8.02
CM-53-12	177.30	0.90	160	14978				21.3	
CM-53-13'	67.60	0.97	65	15043	<0.003	<0.13	<0.003	22.3	
CM-53-14	175.10	-0.03	-6	15038				25.1	8.02
CM-53-15	252.20	1.00	252	15290	0.003	0.13	<0.003	29.1	
CM-53-16	167.10	0.47	78	15368	<0.003	<0.13	<0.003	31.8	
CM-53-17	177.40	-0.17	-30	15338				34.6	8.04
CM-53-18	236.20	1.03	244	15582				38.3	
CM-53-19	324.90	1.03	336	15918				43.5	
CM-53-20	457.10	1.40	640	16558				50.7	8.02

Stable Element Leaching / Accelerated Leach Test

Results for each non-radioactive ALT experiment consists of summary data such as concentrations in the leachate of Al, Ca, Fe, Na, Si, Sr, F-, Cl-, SO₄²⁻, and pH. There are also data blocks of Cumulative Mass Released, and Cumulative Fraction Released for the cations (no source term is available for the anions), as well as figures showing Cumulative Releases. This material is provided in Appendix A. Electronic files are available in which additional information is contained including; the summary, modeling results which indicate if the diffusion model fits the data and the diffusion coefficient for each element, and a series of graphs of the data and modeling results. This is the standard format of output from the ALT computer model. In cases where diffusion coefficients have been determined, modeling elemental releases as water percolates through a heap of slag should be possible.

Leachates from the ALT experiments with non-radioactive slags were all alkaline, some extremely so, with typical pH values ranging between 9.5 and 11.0. Cation chemistry is dominated, on a concentration basis (as opposed to fractional release basis), by releases of Ca followed by either Al or Si depending on the sample type. Leaching of Fe is low, often below detection limits. Concentrations of Sr in the leachate are generally low but easily observed. As indicated by the pH, the dominant anion leached is OH⁻. Releases of the other anions (Cl, F, and SO₄²⁻) are low, with, at most, only about 4 mg of each leached over the course of the experiment. The E series slags leached SO₄²⁻, and F about equally. Both the AS and Q-BOP series leached essentially no F or SO₄²⁻, but did release small quantities of Cl.

One set of leachates was analyzed from each of the two radioactive slags because no radioactivity was detected in most of the leachate samples. These are shown in Table 8. Leachate from several intervals were not analyzed because some counts were observed by LSC for those interval. Comparison of results from the elemental analysis of leachate from the radioactive samples with those of non-radioactive slags indicates that there are significant difference in leachability and therefore, presumably, in composition. Of the elements analyzed for, only very low concentrations of Mn, Si and Na were observed. No Fe, Ca, Sr, or Zn were found. The pH was typically around 7.8. This is in marked contrast to the leachates from the non-radioactive slags which were alkaline and had relatively high concentrations of Ca.

Fractional Releases from the Accelerated Leach Test

Fractional releases of the non-radioactive slags are summarized in Table 8 for Sr, Si, Ca, Al, Fe and Na. Rates for Fe are generally based on detection limits of the ICP for Fe (0.02 ppm), consequently they represent a maximum leach rate. These rates were determined by summing the mass of the element that was leached over the entire test. This value was then divided by the mass of that element in the sample. This was then divided by 11 days. These fractional release rates therefore indicate a simple linear rate. For many of the elements examined in the Accelerated Leach Tests this appears to be a reasonable generalization. However, cumulative fractional releases were quite low, making a prediction of longer term releases uncertain.

Samples in Membranes versus Monoliths

The Q-BOP samples were supplied only as powders, consequently they were leached in dialysis membranes, as described earlier. The AS samples were used as a reference to compare leaching of powders in membranes versus leaching of monoliths. Results are presented for both forms. Figure 6 illustrates leach rates for the AS samples contained in membranes and AS samples that were monoliths. It illustrates that no significant differences between releases from the monolith and the membrane samples were apparent. Leach rates of Si and Ca tended to be tightly clustered for both types of samples. In contrast, rates of Sr, Al, and Na were more spread out, but in no systematic way. This means that leaching from the two types of samples is equivalent, allowing direct comparison of the data from the two.

Diffusion Control

To test if diffusion is the leach rate controlling mechanism for each element examined, data from the leach test was processed through the ALT model. This code calculates a diffusion curve through the data that represents the best fit to the data. It then tests the goodness-of-fit between the model and the data. If this value is less than 5% the fit is taken to be close enough that diffusion is taken to be the release mechanism. Results of this analysis are given in Table 10, in which the goodness-of-fit parameter is given in parenthesis. If the goodness-of-fit can be rounded off to 5 or less, the diffusion coefficient is also given.

Of most interest are the monolithic samples. In all cases, releases of Sr, Ca, and Na were diffusion controlled. Coefficients ranged between 3×10^{-10} and $6 \times 10^{-12} \text{ cm}^2/\text{Sec}$ for Sr, from 6×10^{-9} to 4×10^{-12} for Ca and, from 3×10^{-9} to 3×10^{-11} for Na. Leaching of Al was also generally diffusion controlled (one sample fell outside the 5% acceptance criteria) with coefficients that ranged between 4×10^{-10} and $3 \times 10^{-15} \text{ cm}^2/\text{Sec}$. Releases of Si do not appear to be diffusion controlled. Iron releases are so low that it is difficult to obtain enough data to model. In those samples where concentrations above detection limits were observed, diffusion appears to be rate limiting.

Table 8.
Elemental Concentrations in Two Sets of Leachate from Radioactive Samples

CM-55 ALT 20C		Ca ppm	Fe ppm	Mn ppm	Na ppm	Si ppm	Sr ppm	Zn ppm
CM55 2		-0.015	-0.014	0.003	0.221	0.039	-0.001	-0.003
		-0.004	-0.010	0.071	0.262	0.055	0.000	-0.001
		-0.013	-0.015	0.083	0.145	0.051	-0.001	0.001
	CM55 6	-0.009	-0.005	0.093	0.119	0.028	-0.001	-0.001
	CM55 7	-0.015	-0.015	0.102	0.046	0.020	0.000	0.001
	CM55 8	-0.005	-0.009	0.119	0.042	0.038	0.000	-0.003
	CM55 9	-0.007	-0.006	0.119	0.059	0.026	-0.001	-0.001
	CM55 10	-0.011	-0.005	0.103	0.029	0.020	-0.001	0.002
	CM55 12	-0.012	-0.007	0.096	0.025	0.018	-0.001	-0.001
	CM55 13	-0.016	-0.004	0.099	0.019	0.019	-0.001	-0.001
SEG 00A ALT 20G	seg 00A 2	-0.010	-0.029	0.003	0.040	-0.005	-0.001	0.019
	seg 00A 3	-0.025	-0.038	0.005	0.025	-0.016	-0.001	0.005
		-0.021	-0.042	0.000	0.042	-0.005	-0.001	0.003
	seg 00A 5	-0.026	-0.041	0.002	0.016	-0.027	-0.001	0.002
	seg 00A 6	-0.009	-0.046	0.000	0.037	0.000	-0.001	-0.001
	seg 00A 7	-0.015	-0.041	0.001	0.013	-0.029	-0.001	0.000
	seg 00A 8	-0.029	-0.037	0.002	0.011	-0.027	-0.001	0.002
	seg 00A 9	-0.023	-0.031	0.000	0.021	-0.018	-0.001	0.003
	seg 00A 10	-0.024	-0.031	0.003	0.012	0.000	-0.001	-0.004
	seg 00A 11	-0.010	-0.010	0.007	0.005	-0.002 ^a	0.000	0.000
	seg 00A 12	-0.016	-0.014	0.003	0.015	-0.016	0.000	-0.001
	seg 00A 13	-0.016	-0.010	0.007	0.005	-0.005	-0.001	-0.002

Table 9
Elemental Leaching of Slags in Accelerated Leach Tests
as Fractional Releases /Day

Sample	Description	Sr	Si	Ca	Al	Fe	Na
Q-BOP-A	20 C Membrane	3×10^{-3}	2×10^{-4}	4×10^{-4}	6×10^{-6}	4×10^{-6}	3×10^{-2}
Q-BOP-B	20 C Membrane	4×10^{-3}	4×10^{-4}	3×10^{-4}	1×10^{-1}	4×10^{-6}	2×10^{-2}
O-BOP-C	20 C Membrane	3×10^{-3}	3×10^{-4}	4×10^{-4}	5×10^{-5}	4×10^{-11}	4×10^{-3}
AS-001	20 C Membrane	4×10^{-4}	1×10^4	5×10^{-11}	4×10^{-4}	5×10^{-11}	4×10^{-4}
AS-002	20 C Membrane	4×10^{-1}	2×10^5	8×10^{-11}	4×10^{-3}	6×10^{-6}	4×10^{-3}
AS-003	20 C Membrane	6×10^{-3}	1×10^{-5}	1×10^{-3}	5×10^{-3}	6×10^{-11}	5×10^{-11}
AS-001	60 C Membrane	2×10^{-3}	1×10^3	1×10^{-3}	1×10^{-4}	8×10^{-11}	3×10^{-3}
AS-002	60 C Membrane	2×10^{-3}	9×10^{-4}	8×10^{-11}	3×10^{-4}	7×10^{-11}	3×10^{-3}
AS-003	60 C Membrane	2×10^{-3}	7×10^{-4}	8×10^{-11}	4×10^{-4}	8×10^{-6}	2×10^{-3}
AS-001	20 C Monolith 5 Days	9×10^{-4}	4×10^{-4}	9×10^{-4}	1×10^{-5}	3×10^{-6}	4×10^{-3}
AS-002	20 C Monolith 5 Days	1×10^{-3}	9×10^{-5}	1×10^{-3}	2×10^{-3}	3×10^{-6}	2×10^{-3}
AS-003	20 C Monolith 5 Days	5×10^{-4}	2×10^{-5}	4×10^{-11}	2×10^{-3}	1×10^{-11}	5×10^{-11}
E-1	20 C Monolith	1×10^{-4}	8×10^{-5}	7×10^{-3}	2×10^{-3}	1×10^{-5}	3×10^{-3}
E-2	20 C Monolith	8×10^{-4}	5×10^{-4}	5×10^{-4}	3×10^{-4}	1×10^{-5}	3×10^{-3}
E-3	20 C Monolith	1×10^{-3}	1×10^{-3}	6×10^{-11}	1×10^{-11}	7×10^{-11}	1×10^{-3}
E-1	60 C Monolith	2×10^{-3}	4×10^{-4}	1×10^{-3}	2×10^{-4}	1×10^{-5}	4×10^{-3}
E-2	60 C Monolith	1×10^{-3}	8×10^{-4}	6×10^{-4}	3×10^{-4}	8×10^{-7}	1×10^{-3}
E-3	60 C Monolith	2×10^{-3}	2×10^{-3}	1×10^{-3}	2×10^{-4}	5×10^{-6}	4×10^{-3}

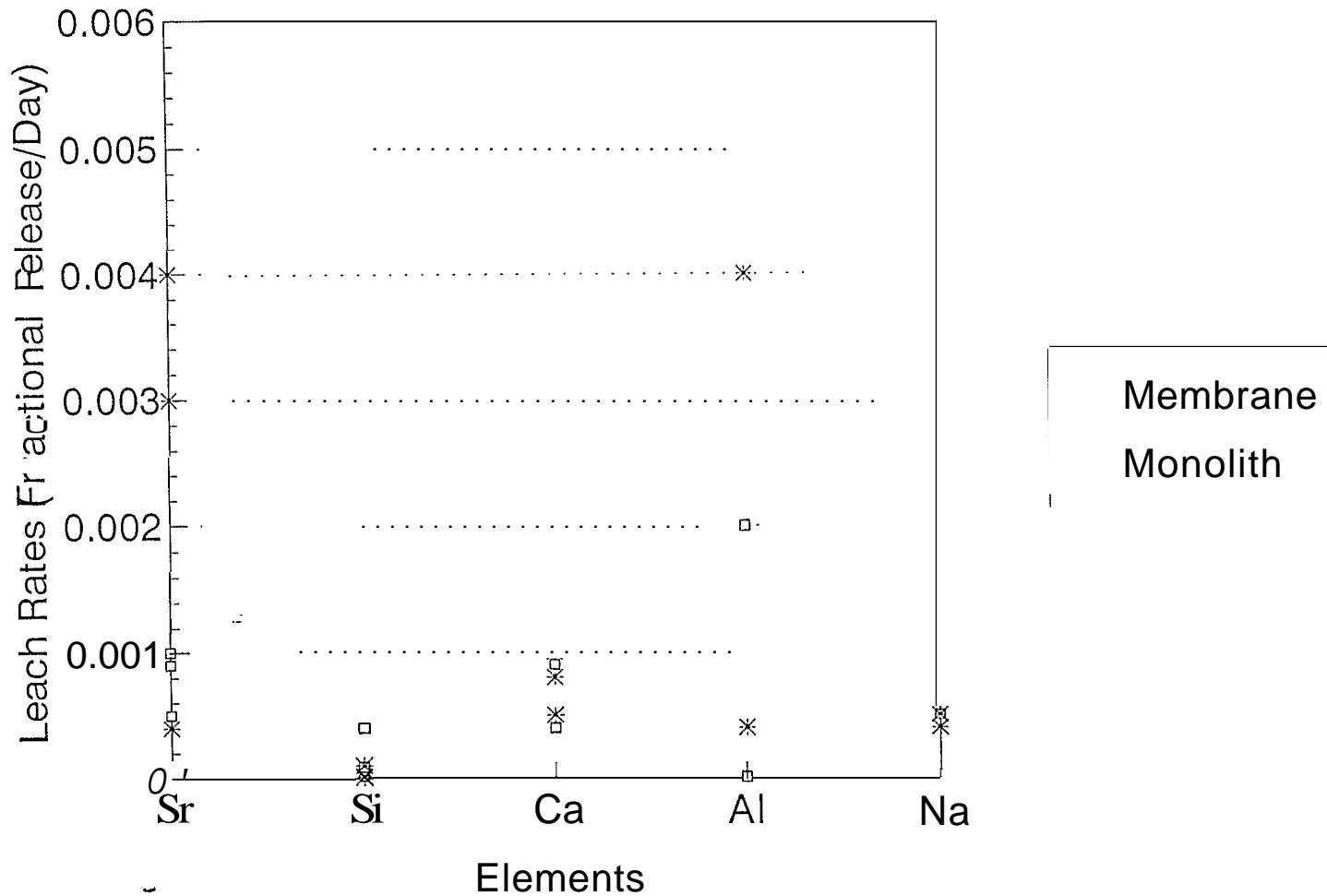


Figure 6. Comparison of fractional releases rates between monolithic samples and powdered samples contained in dialysis membrane. Leach rates of all five elements indicate no difference between the two types of samples.

**Table 10. Elemental Leaching of Slags in Accelerated Leach Tests
Diffusion Coefficients(cm²/Sec) and "Goodness of Fit" of Experimental Data to Model**

Sample	Description	Sr	Si	Ca	Al	Fe	Na
Q-BOP-A	20 C Membrane	(16%)	7×10^{-13} (5.2%)	4×10^{-12} (0.8%)	(10.4%)	NA	(20%)
Q-BOP-B	20 C Membrane	(20.4%)	2×10^{-12} (5.2%)	2×10^{-11} (0.6%)	(7.5%)	NA	(6.2%)
Q-BOP-C	20 C Membrane	(17%)	3×10^{-12} (4.5%)	4×10^{-12} (1.6%)	(6.5%)	NA	4×10^{-10} (4.2%)
AS-001	20 C Membrane	2×10^{-12} (1.4%)	2×10^{-13} (2.7%)	2×10^{-12} (4.2%)	9×10^{-13} (4.1%)	NA	(10.5%)
AS-002	20 C Membrane	(9.1%)	(8.2%)	(6.2%)	(8.6%)	NA	1×10^{-9} (3.5%)
AS-003	20 C Membrane	(45%)	(11.5%)	(20%)	(24%)	NA	(14%)
AS-001	60 C Membrane	(5.9%)	(11.7%)	2×10^{-11} (2.3%)	(12.1%)	NA	2×10^{-10} (2.3%)
AS-002	60 C Membrane	9×10^{-11} (2.0%)	(31.3%)	1×10^{-11} (2.4%)	4×10^{-11} (5.1%)	NA	(16.9%)
AS-003	60 C Membrane	(7.9%)	(17.7%)	2×10^{-11} (0.9%)	5×10^{-11} (2.4%)	NA	5×10^{-10} (0.02%)
AS-001	20 C Monolith 5 Days	1×10^{-11} (1.4%)	3×10^{-12} (1.8%)	2×10^{-11} (1.6%)	3×10^{-15} (2.4%)	NA	6×10^{-10} (0.02%)
AS-002	20 C Monolith 5 Days	3×10^{-11} (0.04%)	(10.3%)	2×10^{-11} (0.07%)	3×10^{-10} (0.4%)	8×10^{-17} (1.2%)	2×10^{-10} (0.02%)
AS-003	20 C Monolith 5 Days	6×10^{-12} (0.3%)	2×10^{-15} (2.9%)	4×10^{-12} (0.07%)	9×10^{-11} (0.01%)	2×10^{-18} (0%)	3×10^{-11} (0.2%)
E-1	20 C Monolith	9×10^{-11} (0.2%)	(7.2%)	6×10^{-9} (0.7%)	4×10^{-10} (1.2%)	NA	2×10^{-9} (1.3%)
E-2	20 C Monolith	2×10^{-11} (5.0%)	(18.2%)	9×10^{-12} (2.7%)	(6.0%)	NA	3×10^{-9} (3.3%)
E-3	20 C Monolith	6×10^{-11} (2.8%)	(5.7%)	2×10^{-11} (1.9%)	7×10^{-13} (0.5%)	NA	5×10^{-10} (2.8%)
E-1	60 C Monolith	3×10^{-10} (0.3%)	(11.5%)	1×10^{-10} (0.4%)	2×10^{-11} (5.3%)	7×10^{-18} (0.05%)	4×10^{-9} (1.2%)
E-2	60 C Monolith	4×10^{-10} (4.4%)	(18%)	3×10^{-10} (0.5%)	2×10^{-11} (3.1%)	5×10^{-20} (2.9%)	4×10^{-10} (0.4%)
E-3	60 C Monolith	4×10^{-10} (4.4%)	(18%)	3×10^{-10} (0.5%)	2×10^{-11} (3.1%)	(6.1%)	3×10^{-9} (1.3%)

Stable Element Leaching / Column Experiments

Three columns contained non-radioactive slags. The leachates from these were sampled and analyzed, in most cases for Al, Ca, Fe, Si, Sr, Na, F, Cl, SO₄, and pH. Results for each column are provided below.

Q-BOP Slag

The column for the Q-BOP slag measured 6.35 cm in length and 3.18 cm inside diameter. The quantity of slag added to the column was 77.81 grams and the porosity was 40.0%. This column was leached for 94.3 days and 6224 mL of distilled water flowed through it over that time. On a mass basis, Ca dominated releases with 3600 mg leached. This was followed by Na at 4.77 mg and Sr at 2.45 mg. Only very small (less than 1 mg) quantities of the structural constituents of the slag (Si, Fe and Al) were released. The leachate was highly alkaline with pH values ranging between 12.4 and 13.1. Results, as fractional releases, are shown in Table 11 and Figure 7. Elemental concentrations for each sampling interval are provided in Appendix B. Releases of all constituents are quite linear over time allowing the mass basis and fractional release rates to be determined as shown in Table 12. Releases rates for Ca and Sr are identical, as expected if the two elements are present in the same components of the slag. Fractional leaching of Fe and Si were very low.

AS-3 Slag

The column used to leach the AS slag measured 6.35 cm in length and 3.18 cm inside diameter. The quantity of slag added to the column was 94.17 grams and the porosity was 42.6%. This column was leached for 81.9 days and 5619 mL of distilled water flowed through it over that time. Releases were dominated by Ca on a mass basis, with 336.6 mg released over the course of the experiment. This was followed by Al at 153.4 mg, 9.9 mg of Si, 4.56 mg of Na, 2.38 mg of Sr, and small quantities of Cl, SO₄, and F. The dominant anion was OH⁻ since the pH ranged from 10.2 to 12. Elemental concentrations for each sampling interval are provided in Appendix B. Releases of Sr, Si and Cl became linear after 20 to 30 days. Leaching of Si accelerated up to 20 days; a process probably caused by the high alkalinity. Leaching of Na, and Al are non-linear and may be diffusion controlled. Leaching of Ca appears similar, initially, but then accelerated at about 60 days. Results, as fractional releases, are shown in Table 13 and Figure 8. Both mass based rates and fractional release rates over the entire course of the experiment are given in Table 14. More realistic rates for long-term projections are provided in Table 15 in which rates are based on the leaching data derived from day 34.3 to day 81.9. These data are relatively linear and are therefore better suited for extrapolation.

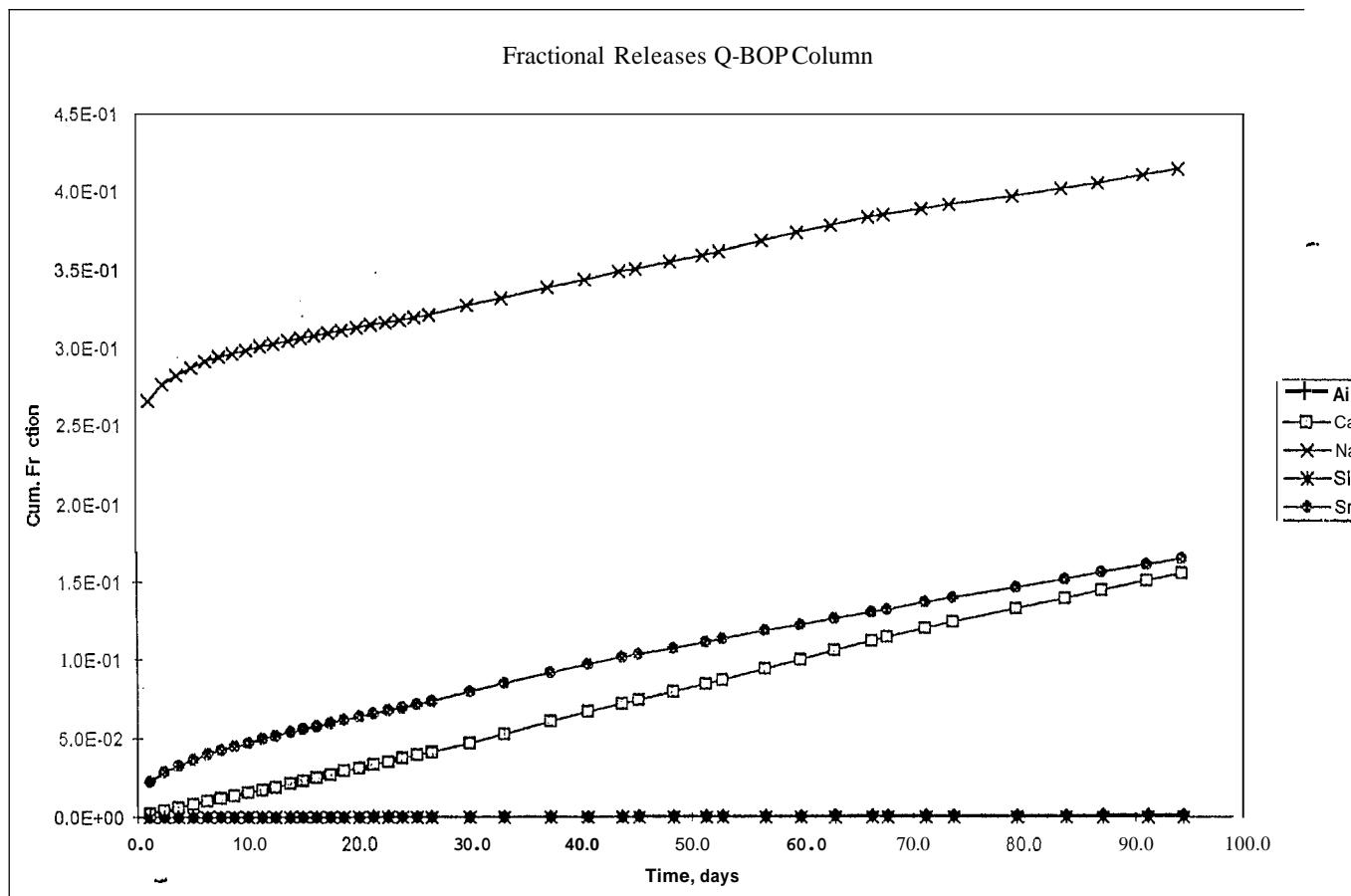


Figure 7. Cumulative fractional releases of elements from the Q-BOP slag over the course of the column experiment. Releases appear to become steady state - linear release rates - after 10 or 20 days.

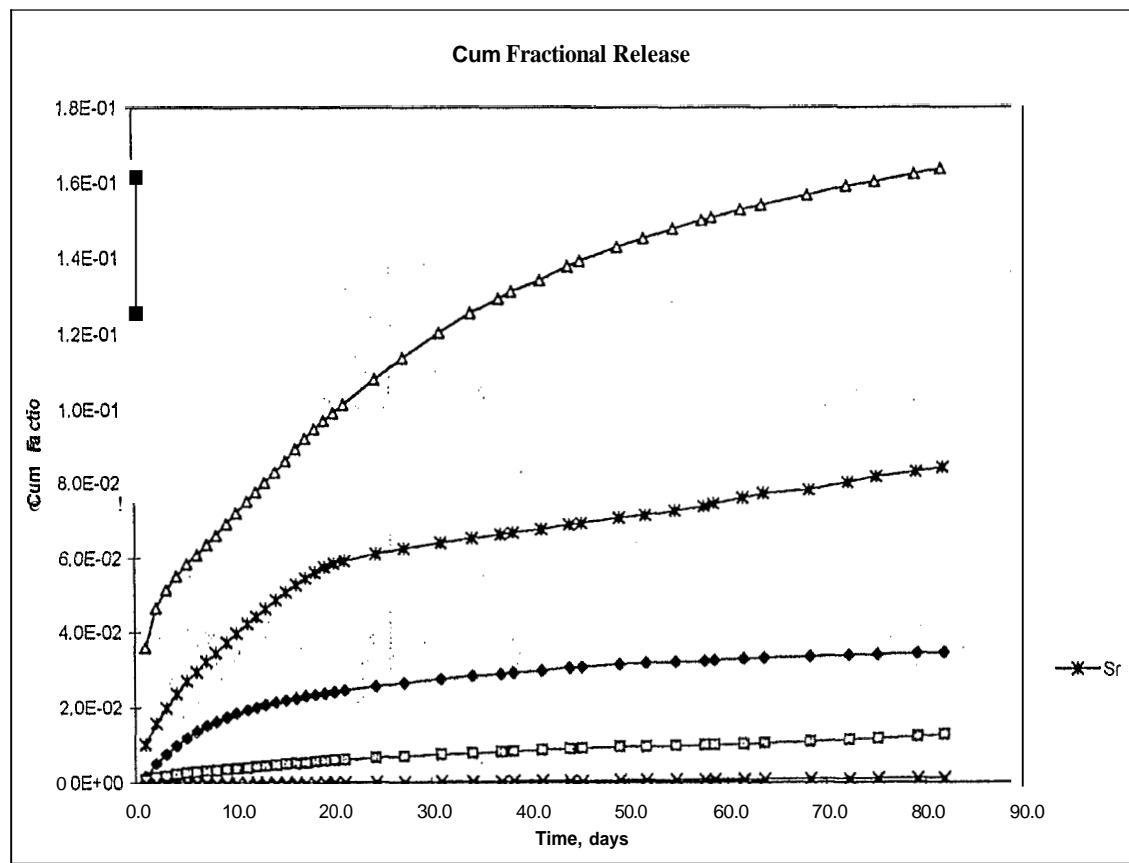


Figure 8. Cumulative fractional releases of elements from the AS-3 slag over the course of the column experiment. Releases for most of the elements appear to become steady state - linear release rates - after about 30 days. The clear exception to this is Na release.

Table 11
Cumulative Fractional Releases of Elements from Slag Column Q-BOP

	Sum Effluent (g)	Time (days)	Al	Ca	Fe	Na	Si	Sr
QBOP A Col 1	71.4	1.1	2.1e-05	2.1e-03	-1.0e-05	2.7e-01	2.0e-06	2.2e-02
QBOP A Col 2	155.3	2.4	3.6e-05	4.1e-03	1.4e-04	2.8e-01	2.4e-06	2.8e-02
QBOP A Col 3	239.8	3.6	4.0e-05	6.1e-03	4.7e-04	2.8e-01	2.6e-06	3.3e-02
QBOP A Col 4	328.2	5.0	6.2e-05	8.1e-03	1.9e-03	2.9e-01	2.7e-06	3.6e-02
QBOP A Col 5	413.9	6.3	6.5e-05	1.0e-02	3.0e-03	2.9e-01	3.0e-06	4.0e-02
QBOP A Col 6	492.7	7.5	7.7e-05	1.2e-02	4.6e-03	2.9e-01	3.0e-06	4.3e-02
QBOP A Col 7	575.7	8.7	8.4e-05	1.4e-02	5.5e-03	3.0e-01	3.1e-06	4.5e-02
QBOP A Col 8	657.4	10.0	9.2e-05	1.5e-02	6.2e-03	3.0e-01	3.2e-06	4.7e-02
QBOP A Col 9	741.5	11.2	9.8e-05	1.7e-02	6.3e-03	3.0e-01	3.3e-06	5.0e-02
QBOP A Col 10	824.0	12.5	9.3e-05	1.9e-02	6.4e-03	3.0e-01	3.4e-06	5.2e-02
QBOP A Col 11	912.5	13.8	1.1e-04	2.1e-02	5.9e-03	3.0e-01	3.5e-06	5.4e-02
QBOP A Col 12	989.2	15.0	1.3e-04	2.3e-02	5.8e-03	3.1e-01	3.6e-06	5.6e-02
QBOP A Col 13	1067.4	16.2	1.4e-04	2.5e-02	5.1e-03	3.1e-01	3.7e-06	5.8e-02
QBOP A Col 14	1151.2	17.4	1.7e-04	2.7e-02	4.5e-03	3.1e-01	3.9e-06	6.0e-02
QBOP A Col 15	1235.2	18.7	1.8e-04	2.9e-02	3.7e-03	3.1e-01	4.0e-06	6.2e-02
QBOP A Col 16	1324.0	20.1	2.0e-04	3.1e-02	2.9e-03	3.1e-01	4.1e-06	6.4e-02
QBOP A Col 17	1411.1	21.4	2.2e-04	3.3e-02	2.2e-03	3.2e-01	4.3e-06	6.6e-02
QBOP A Col 18	1496.1	22.7	2.5e-04	3.5e-02	1.4e-03	3.2e-01	4.5e-06	6.8e-02
QBOP A Col 19	1581.9	24.0	2.6e-04	3.7e-02	7.0e-04	3.2e-01	4.5e-06	7.0e-02
QBOP A Col 20	1668.4	25.3	2.7e-04	3.9e-02	-6.4e-05	3.2e-01	4.7e-06	7.2e-02
QBOP A Col 21	1757.1	26.6	2.8e-04	4.1e-02	-1.0e-04	3.2e-01	5.0e-06	7.4e-02
QBOP A Col 22	1980.6	30.0	3.6e-04	4.7e-02	-2.9e-04	3.3e-01	6.3e-06	8.0e-02
QBOP A Col 23	2184.2	33.1	4.1e-04	5.3e-02	-3.1e-04	3.3e-01	7.5e-06	8.5e-02
QBOP A Col 24	2459.2	37.3	4.7e-04	6.1e-02	-5.4e-04	3.4e-01	9.3e-06	9.2e-02
QBOP A Col 25	2680.5	40.6	5.3e-04	6.7e-02	-7.2e-04	3.4e-01	1.0e-05	9.7e-02
QBOP A Col 26	2883.5	43.7	6.1e-04	7.2e-02	-9.0e-04	3.5e-01	1.1e-05	1.0e-01
QBOP A Col 27	2985.5	45.2	6.4e-04	7.4e-02	-9.2e-04	3.5e-01	1.1e-05	1.0e-01
QBOP A Col 28	3189.3	48.3	7.3e-04	8.0e-02	-1.0e-03	3.6e-01	1.3e-05	1.1e-01
QBOP A Col 29	3385.2	51.3	8.3e-04	8.5e-02	-8.9e-04	3.6e-01	1.4e-05	1.1e-01
QBOP A Col 30	3486.2	52.8	8.5e-04	8.7e-02	-8.9e-04	3.6e-01	1.5e-05	1.1e-01
QBOP A Col 31	3743.2	56.7	9.1e-04	9.4e-02	-9.2e-04	3.7e-01	1.7e-05	1.2e-01
QBOP A Col 32	3951.3	59.9	9.8e-04	1.0e-01	-1.1e-03	3.7e-01	1.9e-05	1.2e-01
QBOP A Col 33	4157.2	63.0	1.1e-03	1.1e-01	-9.9e-04	3.8e-01	2.0e-05	1.3e-01
QBOP A Col 34	4375.7	66.3	1.1e-03	1.1e-01	-9.0e-04	3.8e-01	2.2e-05	1.3e-01
QBOP A Col 35	4467.2	67.7	1.2e-03	1.1e-01	-9.3e-04	3.9e-01	2.3e-05	1.3e-01
QBOP A Col 36	4692.7	71.1	1.2e-03	1.2e-01	-1.1e-03	3.9e-01	2.4e-05	1.4e-01
QBOP A Col 37	4858.8	73.6	1.2e-03	1.2e-01	-1.2e-03	3.9e-01	2.4e-05	1.4e-01
QBOP A Col 38	5237.3	79.4	1.3e-03	1.3e-01	-1.3e-03	4.0e-01	2.6e-05	1.5e-01
QBOP A Col 39	5527.3	83.7	1.4e-03	1.4e-01	-1.5e-03	4.0e-01	2.7e-05	1.5e-01
QBOP A Col 40	5747.7	87.1	1.5e-03	1.4e-01	-1.5e-03	4.1e-01	2.9e-05	1.6e-01
QBOP A Col 41	6013.7	91.1	1.5e-03	1.5e-01	-1.6e-03	4.1e-01	3.1e-05	1.6e-01
QBOP A Col 42	6224.0	94.3	1.6e-03	1.6e-01	-1.7e-03	4.1e-01	3.3e-05	1.6e-01

E-1 Slag

The column for the E-1 slag measured 6.35 cm in length and 3.18 cm inside diameter. The quantity of slag added to the column was 86.18 grams and the porosity was **39.9%**. This column was leached for 41.6 days and 2619 mL of distilled water flowed through it over that time. Elemental concentrations for each sampling interval are provided in Appendix B. Cumulative fractional releases are given in Table 16. Calcium releases dominated with 336 mg, followed by Al with **41.9** mg and Na with 22.5 mg. Small quantities of Sr and Si and no Fe were observed in the leachate. Again the leachate was alkaline with pH values ranging from 11.7 to 12.3. As with the AS-3 slag, leaching was rapid in the first 20-30 days of the experiment and then it became more linear. Based on this observation, two tables of rates were prepared; one for the overall experiment (Table 17) and another for the latter portion (Table 18) in which leaching appears to be generally linear (days 20 to **41.6**). Cumulative fractional releases are also shown in Figure 9.

Table 12.
Release Rates for the Q-BOP Slag in the Column Leaching Experiment

Element	Mass Release Rate (mg/day)	Mass Release Rate (mg/mL)	Fractional Release Rate (fraction/day)	Fractional Release Rate (fraction/mL)
Al	8.4×10^{-3}	1.3×10^{-4}	1.7×10^{-5}	2.6×10^{-7}
Ca	38.2	0.58	1.7×10^{-3}	2.6×10^{-5}
Fe	DL	DL	DL	DL
Na	5.1×10^{-2}	7.7×10^{-4}	4.4×10^{-3}	6.6×10^{-5}
Si	1.9×10^{-3}	2.9×10^{-5}	3.5×10^{-7}	5.3×10^{-9}
Sr	2.6×10^{-2}	3.9×10^{-4}	1.7×10^{-3}	2.6×10^{-5}

Table 13. Cummulative Fractional Releases of Elements from Slag Column AS-3

	Effluent(g)	Days	Al	Ca	Na	Si	Sr
as3 Col 1	73.7	1.1	1.7e-03	6.3e-04	3.6e-02	1.3e-07	1.0e-02
as3 Col 2	143.9	2.1	5.2e-03	1.3e-03	4.7e-02	4.5e-07	1.6e-02
as3 Col 3	214.1	3.1	7.7e-03	1.8e-03	5.2e-02	1.4e-06	2.0e-02
as3 Col 4	288.9	4.2	1.0e-02	2.2e-03	5.5e-02	2.3e-06	2.4e-02
as3 Col 5	360.5	5.3	1.2e-02	2.5e-03	5.8e-02	3.2e-06	2.7e-02
as3 Col 6	425.0	6.2	1.4e-02	2.8e-03	6.1e-02	4.6e-06	3.0e-02
as3 Col 7	494.1	7.2	1.5e-02	3.1e-03	6.4e-02	6.5e-06	3.2e-02
as3 Col 8	562.0	8.2	1.6e-02	3.3e-03	6.6e-02	8.7e-06	3.5e-02
as3 Col 9	632.4	9.2	1.8e-02	3.6e-03	6.9e-02	1.2e-05	3.8e-02
as3 Col 10	701.1	10.2	1.9e-02	3.8e-03	7.2e-02	1.6e-05	4.0e-02
as3 Col 11	776.6	11.3	2.0e-02	4.0e-03	7.5e-02	2.1e-05	4.2e-02
as3 Col 12	839.1	12.2	2.0e-02	4.2e-03	7.8e-02	2.6e-05	4.4e-02
as3 Col 13	903.5	13.2	2.1e-02	4.4e-03	8.0e-02	3.1e-05	4.6e-02
as3 Col 14	973.6	14.2	2.2e-02	4.7e-03	8.3e-02	4.0e-05	4.9e-02
as3 Col 15	1044.3	15.2	2.2e-02	4.9e-03	8.6e-02	5.0e-05	5.1e-02
as3 Col 16	1115.6	16.3	2.3e-02	5.2e-03	8.9e-02	6.1e-05	5.3e-02
as3 Col 17	1184.4	17.3	2.3e-02	5.4e-03	9.2e-02	7.0e-05	5.5e-02
as3 Col 18	1251.6	18.2	2.4e-02	5.6e-03	9.5e-02	8.2e-05	5.6e-02
as3 Col 19	1319.0	19.2	2.4e-02	5.7e-03	9.7e-02	9.3e-05	5.7e-02
as3 Col 20	1387.2	20.2	2.4e-02	5.9e-03	9.9e-02	1.1e-04	5.9e-02
as3 Col 21	1458.1	21.3	2.5e-02	6.1e-03	1.0e-01	1.2e-04	5.9e-02
as3 Col 22	1676.9	24.4	2.6e-02	6.6e-03	1.1e-01	1.7e-04	6.1e-02
as3 Col 23	1873.8	27.3	2.7e-02	7.0e-03	1.1e-01	2.2e-04	6.2e-02
as3 Col 24	2133.6	31.1	2.8e-02	7.5e-03	1.2e-01	2.9e-04	6.4e-02
as3 Col 25	2350.6	34.3	2.9e-02	7.9e-03	1.3e-01	3.5e-04	6.5e-02
as3 Col 26	2547.8	37.1	2.9e-02	8.3e-03	1.3e-01	4.3e-04	6.6e-02
as3 Col 27	2633.8	38.4	3.0e-02	8.4e-03	1.3e-01	4.5e-04	6.7e-02
as3 Col 28	2831.9	41.3	3.0e-02	8.7e-03	1.3e-01	5.1e-04	6.8e-02
as3 Col 29	3024.4	44.1	3.1e-02	9.1e-03	1.4e-01	5.6e-04	6.9e-02
as3 Col 30	3110.8	45.3	3.1e-02	9.3e-03	1.4e-01	5.8e-04	6.9e-02
as3 Col 31	3372.0	49.1	3.2e-02	9.5e-03	1.4e-01	6.7e-04	7.1e-02
as3 Col 32	3552.3	51.8	3.2e-02	9.7e-03	1.5e-01	7.3e-04	7.1e-02
as3 Col 33	3758.3	54.8	3.2e-02	9.9e-03	1.5e-01	8.2e-04	7.3e-02
AS Col 34	3962.5	57.8	3.3e-02	1.0e-02	1.5e-01	8.6e-04	7.4e-02
AS Col 35	4030.5	58.7	3.3e-02	1.0e-02	1.5e-01	8.8e-04	7.5e-02
AS Col 36	4232.5	61.7	3.3e-02	1.0e-02	1.5e-01	9.2e-04	7.6e-02
AS Col 37	4374.2	63.8	3.3e-02	1.1e-02	1.5e-01	9.5e-04	7.7e-02
AS Col 38	4694.4	68.4	3.4e-02	1.1e-02	1.6e-01	1.0e-03	7.8e-02
AS Col 39	4964.8	72.4	3.4e-02	1.1e-02	1.6e-01	1.1e-03	8.0e-02
AS Col 40	5160.8	75.2	3.4e-02	1.2e-02	1.6e-01	1.1e-03	8.2e-02
AS Col 41	5432.5	79.2	3.5e-02	1.2e-02	1.6e-01	1.2e-03	8.3e-02
AS Col 42	5618.7	81.9	3.5e-02	1.3e-02	1.6e-01	1.3e-03	8.4e-02

Table 14.
Overall Release Rates for the AS-3 Slag in the Column Leaching Experiment

Element	Mass Release Rate (mg/day)	Mass Release Rate (mg/mL)	Fractional Release Rate (fraction/day)	Fractional Release Rate (fraction/mL)
Al	1.87	2.7×10^{-2}	4.3×10^{-6}	6.2×10^{-6}
Ca	4.11	6.0×10^{-2}	1.6×10^{-6}	2.3×10^{-6}
Fe	NA	NA	NA	NA
Na	5.6×10^{-2}	8.1×10^{-4}	2.0×10^{-3}	2.8×10^{-5}
Si	1.2×10^{-1}	1.8×10^{-3}	2×10^{-5}	2.3×10^{-7}
Sr	2.9×10^{-2}	4.2×10^{-4}	1.0×10^{-3}	6.2×10^{-6}
F	7.3×10^{-6}	1×10^{-5}	NA	NA
Cl	2.2×10^{-2}	3.2×10^{-4}	NA	NA
SO ₄	2.0×10^{-2}	2.9×10^{-4}	NA	NA

Table 15.
**Release Rates for Latter Portions of Curves for the AS-3 Slag
in the Column Leaching Experiment***

Element	Mass Release Rate (mg/day)	Mass Release Rate (mg/mL)	Fractional Release Rate (fraction/day)	Fractional Release Rate (fraction/mL)
Al	0.56	8.2×10^{-3}	1.3×10^{-4}	1.8×10^{-6}
Ca	2.68	3.9×10^{-2}	1.1×10^{-6}	1.6×10^{-6}
Fe	NA	NA	NA	NA
Na	2.2×10^{-2}	3.2×10^{-4}	6.3×10^{-4}	9.2×10^{-6}
Si	1.5×10^{-1}	2.2×10^{-3}	2×10^{-5}	2.9×10^{-7}
Sr	1.1×10^{-2}	1.7×10^{-4}	4.0×10^{-4}	5.8×10^{-6}
F	0	0	NA	NA
Cl	1.8×10^{-2}	2.6×10^{-4}	NA	NA
SO ₄	1.4×10^{-2}	2.1×10^{-4}	NA	NA

* based on releases from day 34.3 to day 81.9

Table 16.
Cummulative Fractional Releases of Elements from Slag Column E-1

	Effluent (g)	Days	Al	Ca	Fe	Na	Si	Sr
E1 Col 1	64.3	1.0	1.22e-03	6.60e-04	4.73e-08	8.62e-02	2.81e-06	2.10e-02
E1 Col 12	134.7	2.1	2.30e-03	1.25e-03	3.89e-08	1.47e-01	5.62e-06	3.31e-02
E1 Col 3	178.8	2.8	3.02e-03	1.61e-03	4.72e-08	1.79e-01	7.24e-06	3.75e-02
E1 Col 4	250.8	4.0	4.32e-03	2.32e-03	1.03e-07	2.32e-01	8.04e-06	4.29e-02
E1 Col 5	404.5	6.4	4.66e-03	3.52e-03	1.97e-07	3.21e-01	9.92e-06	5.19e-02
E1 Col 6	441.0	7.0	4.76e-03	3.81e-03	2.39e-07	3.32e-01	1.28e-05	5.31e-02
E1 Col 7	470.0	7.5	4.89e-03	4.03e-03	2.96e-07	3.42e-01	1.32e-05	5.42e-02
E1 Col 8	641.2	10.2	5.19e-03	5.44e-03	5.47e-07	3.76e-01	1.37e-05	6.19e-02
E1 Col 9	717.3	11.4	5.30e-03	6.07e-03	5.63e-07	3.86e-01	1.90e-05	6.58e-02
E1 Col 10	829.1	13.2	5.42e-03	6.89e-03	7.04e-07	3.96e-01	2.05e-05	7.15e-02
E1 Col 11	894.8	14.2	5.51e-03	7.29e-03	7.08e-07	4.00e-01	2.39e-05	7.39e-02
E1 Col 12	1088.7	17.3	5.69e-03	8.23e-03	3.43e-07	4.09e-01	2.96e-05	7.97e-02
E1 Col 13	1166.2	18.5	5.75e-03	8.55e-03	3.80e-07	4.12e-01	7.32e-05	8.15e-02
E1 Col 14	1225.1	19.4	5.78e-03	8.73e-03	4.21e-07	4.13e-01	9.82e-05	8.28e-02
E1 Col 15	1339.4	21.3	5.84e-03	8.96e-03	4.91e-07	4.17e-01	1.19e-04	8.41e-02
E1 Col 16	1534.9	24.4	5.94e-03	9.56e-03	4.78e-07	4.22e-01	1.63e-04	8.69e-02
E1 Col 17	1607.8	25.5	5.97e-03	9.89e-03	4.33e-07	4.24e-01	2.52e-04	8.81e-02
E1 Col 18	1798.4	28.5	6.04e-03	1.05e-02	3.35e-07	4.29e-01	2.90e-04	9.08e-02
Col 19	1987.7	31.6	6.12e-03	1.12e-02	4.46e-07	4.33e-01	3.77e-04	9.34e-02
E1 Col 20	2248.4	35.7	6.21e-03	1.23e-02	3.89e-07	4.38e-01	4.75e-04	9.69e-02
E1 Col 21	2428.1	38.5	6.30e-03	1.32e-02	5.88e-07	4.41e-01	6.22e-04	9.92e-02
E1 Col 22	2618.5	41.6	6.31e-03	1.32e-02	1.25e-04	4.42e-01	7.17e-04	9.92e-02

71

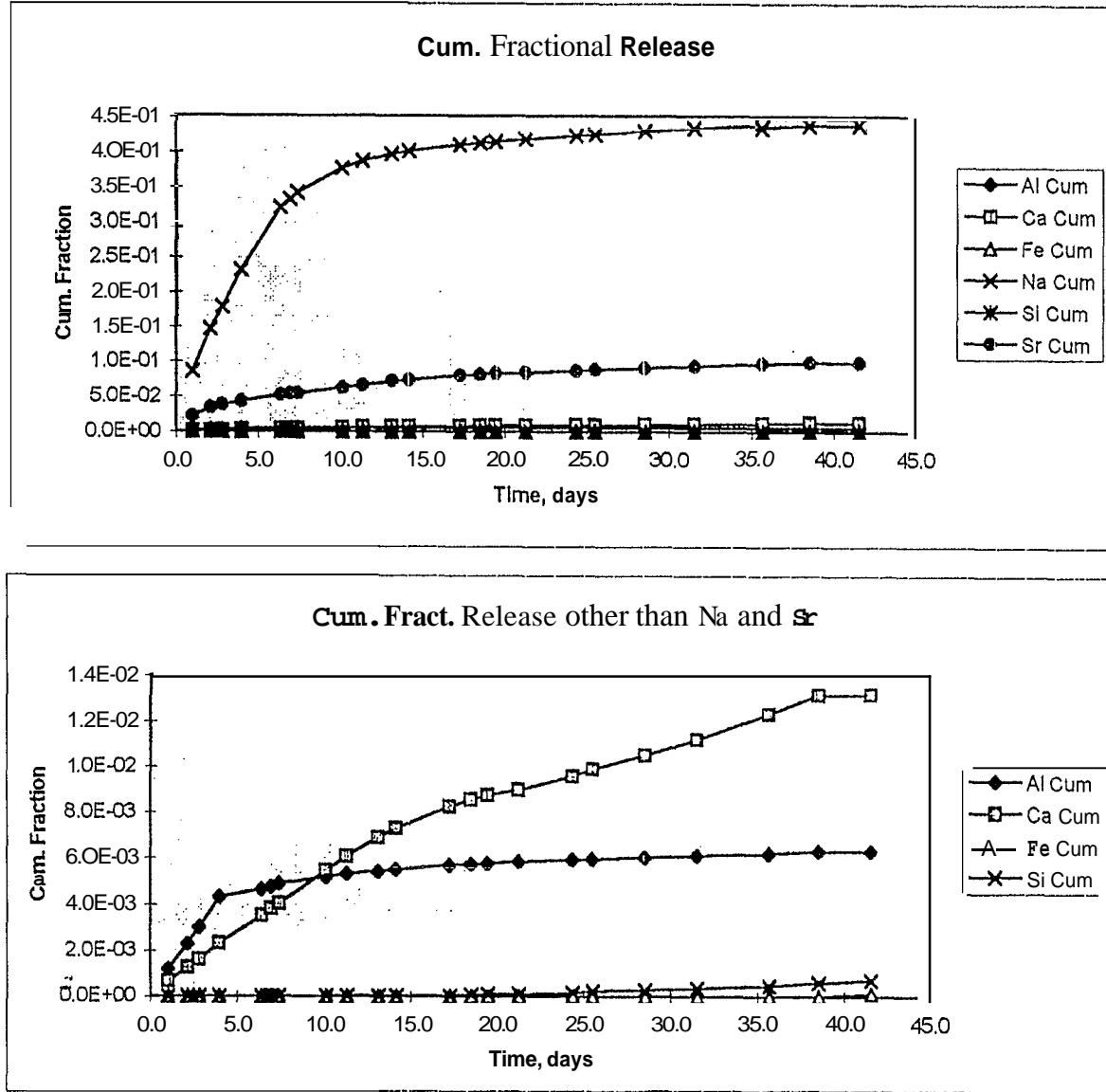


Figure 9. Cumulative fractional releases of elements from the E-1 slag over the course of the column experiment. Releases for most of the elements appear to become steady state - linear release rates - after about 10 days. The clear exception to this is Na release.

Table 17.
Overall Release Rates for the E-1 Slag in the Column Leaching Experiment

Element	Mass Release Rate (mg/day)	Mass Release Rate (mg/mL)	Fractional Release Rate (fraction/day)	Fractional Release Rate (fraction/mL)
Al	1.09	1.7×10^{-2}	1.6×10^{-4}	2.6×10^{-6}
Ca	8.73	1.3×10^{-1}	3.4×10^{-4}	5.4×10^{-6}
Fe	0	0	1.5×10^{-8}	2.4×10^{-10}
Na	0.58	9.3×10^{-3}	1.1×10^{-2}	1.8×10^{-4}
Si	0.08	1.2×10^{-3}	1.6×10^{-5}	2.6×10^{-7}
Sr	0.05	8.1×10^{-4}	2.6×10^{-3}	4.1×10^{-5}
F	0.05	8.8×10^{-4}	NA	NA
Cl	0.04	5.6×10^{-4}	NA	NA
SO ₄	0.14	2.2×10^{-3}	NA	NA

Table 18.
Release Rates for Latter Portions of Curves for the E-1 Slag
in the Column Leaching Experiment*

Element	Mass Release Rate (mg/day)	Mass Release Rate (mg/mL)	Fractional Release Rate (fraction/day)	Fractional Release Rate (fraction/mL)
Al	0.17	2.7×10^{-3}	2.5×10^{-4}	3.9×10^{-6}
Ca	5.19	8.2×10^{-2}	2.0×10^{-4}	3.1×10^{-6}
Fe	0	0	0	0
Na	0.07	1.1×10^{-3}	1.3×10^{-3} (0.3 x 10) ⁻³	2×10^{-5} - 0
Si	0.12	1.9×10^{-3}	3.0×10^{-4}	4.7×10^{-6}
Sr	0.02	2.5×10^{-4}	7.8×10^{-4}	1.2×10^{-5}
F	0.05	8.3×10^{-4}	NA	NA
Cl	0.02	3.3×10^{-4}	NA	NA
SO ₄	0.05	7.9×10^{-4}	NA	NA

* from day 17.3 to day 38.5.

Conclusions

In all of the ALT experiments on radioactive slags, no radioactivity was observed by gamma-spectroscopy and with a few exceptions only very low count rates by LSC in the leachate. The counts in the low energy window are very likely background. Higher activity was observed in the column than in the ALT tests; reasonable because of the greater mass and surface area of the solid and smaller volume of water per unit time. The highest activities were found at the beginning of the tests. For the SEG slag in the column experiment, gamma-spectroscopy detected small activities of ^{137}Cs in the first 1200 mL of effluent. After that none was observed. The LSC data for this column showed a linear release rate at 4.3 cpm/g. Leachate from the CM column showed a pattern similar to the SEG slag for ^{137}Cs ; low activities were detected up to a volume of about 1500 mL of effluent. After that none was detected. The LSC data show a more typical leaching profile than does the CM column. These data strongly imply that, at least for this sample, the LSC data are the result of a radionuclide release. Uranium daughter radionuclides were observed in the slag. The column leachate with the greatest activity by LSC was counted by gamma-spectroscopy. No ^{238}U daughters were observed above background levels.

For radionuclides, release rates have been calculated. With the exception of Cs, these rates are based on detection limits and the source terms of the slags. Actual rates may be significantly lower.

Elemental releases from the slags can be useful as analog elements (e.g. Sr for ^{90}Sr) and to define the chemistry that would take place in and under a slag heap. In addition, releases of elements that are major structural components of the slag can indicate the releases of radionuclides that would occur as the slag weathers. Leaching of Fe is undetectable, reasonable considering the alkalinity and reducing condition of the material. Release rates of Si for the latter portions of column tests are on the order of 10^{-4} to 10^{-7} (fraction release/day), for Al they are 10^{-4} to 10^{-5} . Releases of Si appear to have a different controlling mechanism than the other elements examined. Si releases often started low and then accelerated over time. This is possibly due to an increase in pH over time. At high pH, the solubility of Si in water increases dramatically.

The leachate chemistry of the radioactive slags is significantly different than that of the non-radioactive slags. While the leachates from radioactive slags had almost neutral pH and very low to undetectable concentrations of Ca, Si, Al, and other elements, leachate from non-radioactive slags was highly alkaline and had high concentrations of Ca and, often, either Al or Si. These differences demonstrate that the chemistry of the radioactive slag is significantly different than the non-radioactive slag. This is not surprising since they were apparently made by different processes, with different slag forming additives. Investigation of both is useful, in the sense of radionuclide leaching, because a number of cases of slag from non-radioactive steel recycling have been reported. The cause is generally incorporation of a ^{137}Cs or ^{60}Co source used in manufacturing (e.g. sheetmetal thickness gauges) into the steel being recycled. More importantly, if slightly contaminated steels were to be released for general recycling, release rates from these slags will be needed.

Due to very high concentrations in column leachates, precipitates were observed in the column itself and in the tubing leading from the outlet to the sample container. This is probably a CaCO_3 , but other phases are possible given the high Al and Si concentrations in the leachate and the high pH. Fe-hydroxide precipitation was observed in one column experiment (CM column) . The precipitate occurred as a colloidal aggregate. The formation of secondary phases, such as Fe-hydroxides, alumino-silicates, and calcium carbonates, upon exposure of slags to water results in controls on the release of contaminants and even cementing of the slag. On one hand, the precipitation of these secondary phases may attenuate the transport of contaminants; while on the other hand, the formation of colloidal particles may facilitate the transport of contaminants. From the data presented in this report, it is evident that for the alkaline rich slags, geochemical reactions within and beneath the slag deposit could significantly impact transport of contaminants over long times.

In summary, releases rates of radionuclides and other structural elements from slags from steel recycling have been experimentally determined. Often releases are so low that only maximum rates were calculated based on detection limits and source term masses. Given the low release rates, another approach to long-term behavior of elements in slags may prove beneficial. Identification of mineral phases in the slag and determinations of trace elements in those phases by microprobe could be used to do two things. First, determine the phases into which elements such as U would partition and second, estimate the response of those phases to weathering over long times, including release rates.

APPENDIX A

Summary

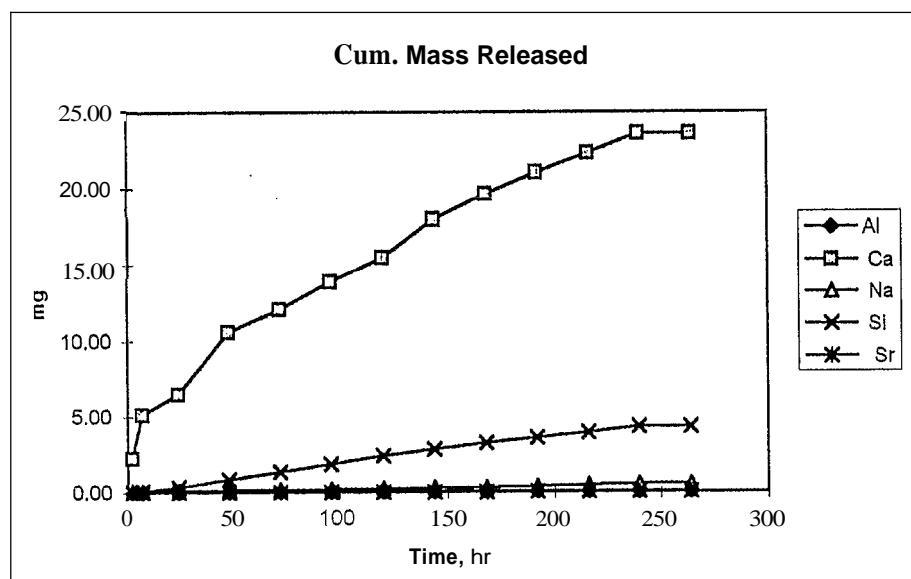
Experiment Q-BOP-A
Temp(C) 20
material powder in membrane
volume(mL) 200

	Concentration (ppm)										
	time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH
QBOPA-1	2	0.04	11.22	0.01	0.47	0.11	0.01	n.a.	n.a.	n.a.	9.30
QBOPA-2	7	-0.02	14.58	0.01	0.04	0.26	0.00	n.a.	n.a.	n.a.	
QBOPA-3	24	0.07	6.75	0.00	0.13	1.39	0.01	n.a.	n.a.	n.a.	10.20
QBOPA-4	48	0.07	20.44	0.01	0.14	2.55	0.02	n.a.	n.a.	n.a.	10.50
QBOPA-5	72	0.01	7.33	0.01	0.14	2.46	0.01	n.a.	n.a.	n.a.	10.10
QBOPA-6	96	0.04	9.18	0.00	0.10	2.51	0.01	n.a.	n.a.	n.a.	10.40
QBOPA-7	120	0.00	8.15	-0.02	0.20	2.83	0.02	n.a.	n.a.	n.a.	10.00
QBOPA-8	144	0.03	12.26	-0.02	0.17	2.18	0.01	n.a.	n.a.	n.a.	10.32
QBOPA-9	168	-0.01	8.39	-0.01	0.16	2.10	0.01	n.a.	n.a.	n.a.	9.35
QBOPA-10	192	0.00	7.02	-0.01	0.40	1.68	0.03	n.a.	n.a.	n.a.	9.70
QBOPA-11	216	0.00	6.20	-0.01	0.41	1.73	0.03	n.a.	n.a.	n.a.	9.78
QBOPA-12	240	0.02	6.52	-0.01	0.30	1.90	0.03	n.a.	n.a.	n.a.	
QBOPA-13	264										10.05

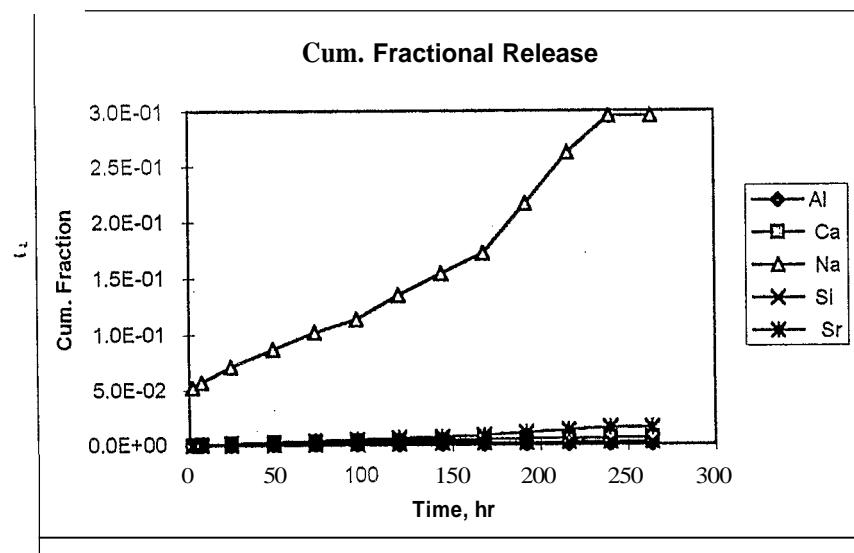
time(hrs)	Cumulative Mass Released (mg)								Cumulative Fractional Releases (cations)				
	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr
E3-20-1	2	0.01	2.24	0.09	0.02	0.00	n.a.	n.a.	9.8E-05	6.1E-04	5.3E-02	1.1E-05	4.5E-04
E3-20-2	7	0.00	5.16	0.10	0.07	0.00	n.a.	n.a.	4.2E-05	1.4E-03	5.7E-02	3.9E-05	7.4E-04
QBOPA-3	24	0.02	6.51	0.13	0.35	0.00	n.a.	n.a.	2.3E-04	1.8E-03	7.1E-02	1.9E-04	1.5E-03
QBOPA-4	48	0.03	10.60	0.16	0.86	0.01	n.a.	n.a.	4.0E-04	2.9E-03	8.6E-02	4.6E-04	2.9E-03
QBOPA-5	72	0.03	12.06	0.18	1.35	0.01	n.a.	n.a.	4.2E-04	3.3E-03	1.0E-01	7.2E-04	4.1E-03
QBOPA-6	96	0.04	13.90	0.20	1.85	0.01	n.a.	n.a.	5.0E-04	3.8E-03	1.1E-01	9.9E-04	5.1E-03
QBOPA-7	120	0.04	15.53	0.24	2.42	0.02	n.a.	n.a.	5.0E-04	4.2E-03	1.3E-01	1.3E-03	6.5E-03
QBOPA-8	144	0.05	17.98	0.28	2.86	0.02	n.a.	n.a.	5.6E-04	4.9E-03	1.5E-01	1.5E-03	7.7E-03
QBOPA-9	168	0.04	19.66	0.31	3.28	0.02	n.a.	n.a.	5.4E-04	5.4E-03	1.7E-01	1.7E-03	8.9E-03
QBOPA-10	192	0.04	21.06	0.39	3.61	0.03	n.a.	n.a.	5.5E-04	5.8E-03	2.2E-01	1.9E-03	1.1E-02
QBOPA-11	216	0.04	22.30	0.47	3.96	0.03	n.a.	n.a.	5.5E-04	6.1E-03	2.6E-01	2.1E-03	1.3E-02
QBOPA-12	240	0.05	23.61	0.53	4.34	0.04	n.a.	n.a.	6.1E-04	6.5E-03	3.0E-01	2.3E-03	1.6E-02
QBOPA-13	264	0.05	23.61	0.53	4.34	0.04	n.a.	n.a.	6.1E-04	6.5E-03	3.0E-01	2.3E-03	1.6E-02

Summary

Q3OPA-13	264	0.05	23.61	0.53	4.34	0.04	0.00	0.00	0.00	6.1E-04	6.5E-03	3.0E-01	2.3E-03	1.6E-02
Experiment	Q-BOP-A													



no anion data available

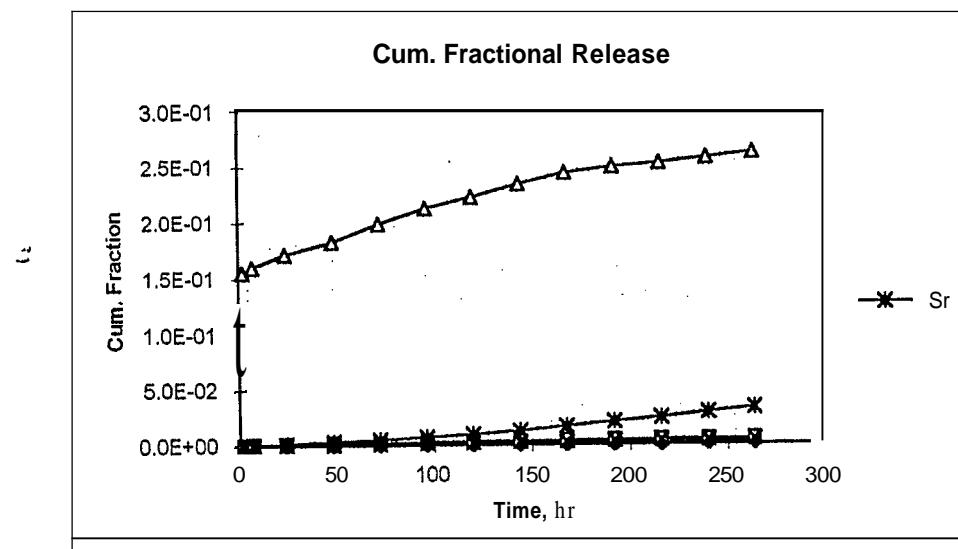
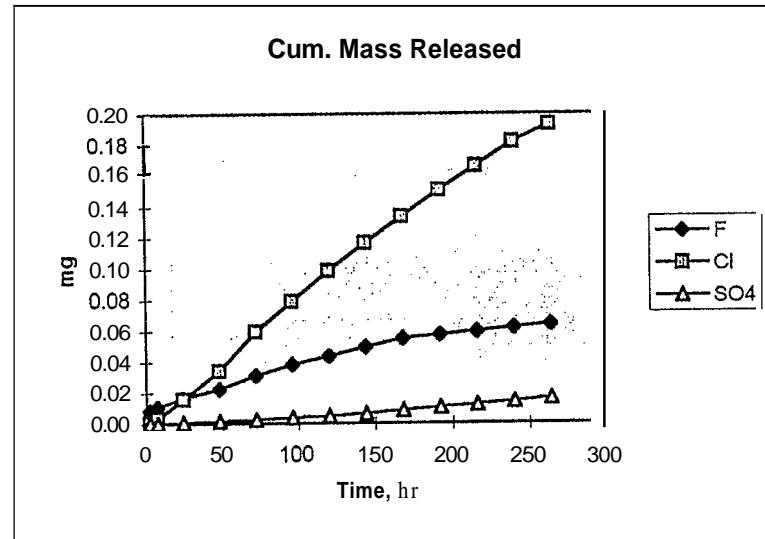
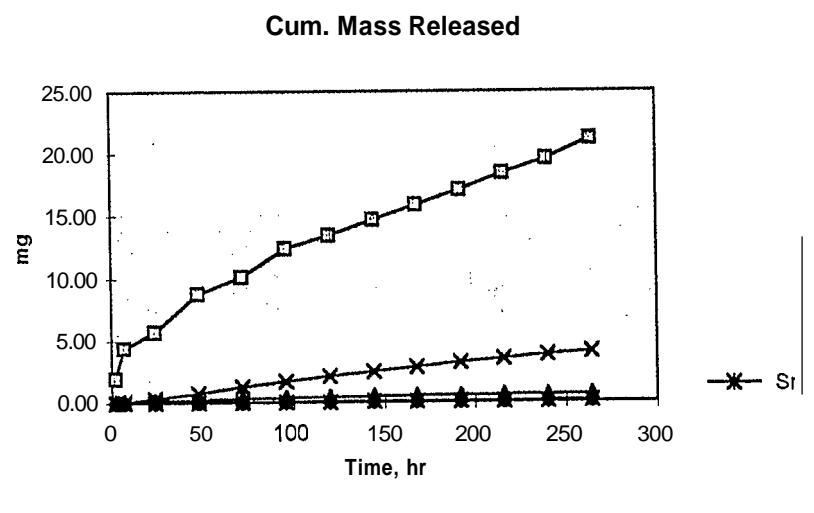


Summary

Experiment	Q-BOP-B												
Temp(C)	20												
material	powder in membrane												
volume(mL)	200												
	Concentration (ppm)												
time(hrs)	Al	Ca	Fc	Na	Si	Sr	F	Cl	SO4	pH			
QBOPB-1	2	0.00	9.56	-0.01	0.39	0.09	0.01	0.04	0.00	10.50			
QBOPB-2	7	0.00	12.34	-0.01	0.12	0.28	0.00	0.01	0.01	10.60			
QBOPB-3	24	0.03	6.50	-0.01	0.29	1.30	0.01	0.03	0.06	10.32			
QBOPB-4	48	0.05	15.26	-0.01	0.28	1.92	0.02	0.03	0.09	10.80			
QBOPB-5	72	0.05	6.71	-0.01	0.40	2.67	0.02	0.04	0.13	10.12			
QBOPB-6	96	0.05	11.48	-0.01	0.34	2.09	0.03	0.04	0.10	10.52			
QBOPB-7	120	-0.01	5.29	-0.01	0.25	2.02	0.03	0.03	0.10	10.02			
QBOPB-8	144	0.05	6.25	-0.01	0.28	1.91	0.04	0.03	0.09	9.55			
QBOPB-9	168	0.03	5.84	0.00	0.25	1.78	0.05	0.03	0.08	9.90			
QBOPB-10	192	0.04	6.02	0.00	0.13	1.83	0.05	0.01	0.09	0.01			
QBOPB-11	216	0.05	6.65	-0.01	0.09	1.60	0.04	0.01	0.08	0.01			
QBOPB-12	240	0.05	5.76	0.00	0.12	1.61	0.06	0.01	0.08	0.01			
QBOPB-13	264	0.05	8.06	-0.01	0.12	1.21	0.05	0.01	0.06	10.52			
	Cumulative Mass Released (mg)												
time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr
QBOPB-1	2	0.00	1.91	0.08	0.02	0.00	0.01	0.00	0.0E+00	4.8E-04	1.6E-01	2.1E-05	4.6E-04
QBOPB-2	7	0.00	4.38	0.10	0.07	0.00	0.01	0.00	1.7E-09	1.1E-03	1.6E-01	8.3E-05	8.4E-04
QBOPB-3	24	0.01	5.68	0.16	0.33	0.00	0.02	0.02	6.7E-05	1.4E-03	1.7E-01	3.7E-04	1.8E-03
QBOPB-4	48	0.02	8.73	0.21	0.72	0.01	0.02	0.03	1.9E-04	2.2E-03	1.8E-01	8.0E-04	3.3E-03
QBOPB-5	72	0.03	10.07	0.30	1.25	0.01	0.03	0.06	3.2E-04	2.5E-03	2.0E-01	1.4E-03	5.2E-03
QBOPB-6	96	0.03	12.37	0.36	1.67	0.02	0.04	0.08	4.4E-04	3.1E-03	2.1E-01	1.9E-03	7.4E-03
QBOPB-7	120	0.03	13.43	0.41	2.07	0.02	0.04	0.10	4.2E-04	3.4E-03	2.2E-01	2.3E-03	9.6E-03
QBOPB-8	144	0.04	14.68	0.47	2.45	0.03	0.05	0.12	5.4E-04	3.7E-03	2.3E-01	2.7E-03	1.3E-02
QBOPB-9	168	0.05	15.85	0.52	2.81	0.04	0.05	0.13	6.3E-04	4.0E-03	2.4E-01	3.1E-03	1.7E-02
QBOPB-10	192	0.06	17.05	0.55	3.17	0.05	0.06	0.15	7.4E-04	4.3E-03	2.5E-01	3.5E-03	2.1E-02
QBOPB-11	216	0.07	18.38	0.56	3.50	0.06	0.06	0.17	8.7E-04	4.6E-03	2.5E-01	3.9E-03	2.4E-02
QBOPB-12	240	0.08	19.53	0.59	3.82	0.07	0.06	0.18	1.0E-03	4.9E-03	2.6E-01	4.3E-03	2.9E-02
QBOPB-13	264	0.09	21.14	0.61	4.06	0.08	0.06	0.19	1.1E-03	5.3E-03	2.6E-01	4.5E-03	3.3E-02

Summary

Experiment Q-BOP-B



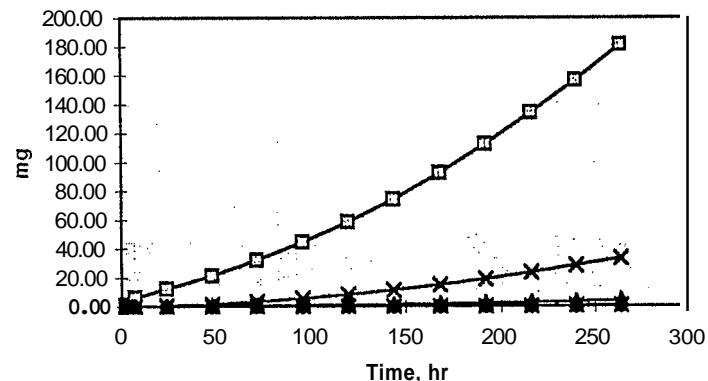
Summary

Experiment	Q-BOP-C												
Temp(C)	20												
material	powder in membrane												
volume(mL)	200												
	Concentration (ppm)												
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4				
QBOPC-1	2	0.00	7.50	-0.01	0.19	0.06	0.00	n.a.	n.a.	10.45			
QBOPC-2	7	0.00	21.65	-0.02	0.22	0.31	0.01	n.a.	n.a.	10.70			
QBOPC-3	24	0.00	30.73	-0.04	0.42	1.75	0.02	n.a.	n.a.	10.60			
QBOPC-4	48	0.05	46.12	-0.05	0.65	4.63	0.03	n.a.	n.a.	10.70			
QBOPC-5	72	0.06	53.38	-0.06	1.04	8.21	0.06	n.a.	n.a.	10.30			
QBOPC-6	96	0.09	62.78	-0.08	1.31	11.01	0.08	n.a.	n.a.	10.52			
QBOPC-7	120	0.10	70.28	-0.09	1.53	13.67	0.10	n.a.	n.a.	9.60			
QBOPC-8	144	0.08	78.14	-0.11	1.73	16.04	0.12	n.a.	n.a.	9.60			
QBOPC-9	168	0.12	91.41	-0.11	2.07	18.22	0.16	n.a.	n.a.	9.70			
QBOPC-10	192	0.14	99.30	-0.11	2.30	20.33	0.19	n.a.	n.a.				
QBOPC-11	216	0.13	107.47	-0.12	2.45	22.30	0.21	n.a.	n.a.	9.25			
QROPC-12	240	0.17	114.17	-0.12	2.70	23.96	0.26	n.a.	n.a.	10.30			
QBOPC-13	264	0.20	122.00	-0.13	2.83	25.33	0.30	n.a.	n.a.	10.22			
	Cumulative Mass Released (mg)												
time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Cumulative Fractional Releases (cations)				
E3-20-1	2	0.00	1.50	0.04	0.01	0.00	n.a.	n.a.	0.0E+00	4.1E-04	7.6E-03	1.1E-05	1.7E-04
E3-20-2	7	0.00	5.83	0.08	0.07	0.00	n.a.	n.a.	0.0E+00	1.6E-03	1.6E-02	6.9E-05	1.7E-04
QBOPC-3	24	0.00	11.98	0.17	0.42	0.00	n.a.	n.a.	0.0E+00	3.3E-03	3.3E-02	4.0E-04	1.7E-04
QBOPC-4	48	0.01	21.20	0.30	1.35	0.01	n.a.	n.a.	6.9E-05	5.8E-03	5.9E-02	1.3E-03	1.8E-04
QBOPC-5	72	0.02	31.87	0.50	2.99	0.02	n.a.	n.a.	1.5E-04	8.8E-03	1.0E-01	2.8E-03	1.8E-04
QBOPC-6	96	0.04	44.43	0.77	5.19	0.04	n.a.	n.a.	2.9E-04	1.2E-02	1.5E-01	4.9E-03	1.9E-04
QBOPC-7	120	0.06	58.49	1.07	7.93	0.06	n.a.	n.a.	4.3E-04	1.6E-02	2.1E-01	7.4E-03	1.9E-04
QBOPC-8	144	0.08	74.11	1.42	11.14	0.08	n.a.	n.a.	5.6E-04	2.0E-02	2.8E-01	1.0E-02	2.0E-04
QBOPC-9	168	0.10	92.40	1.83	14.78	0.11	n.a.	n.a.	7.3E-04	2.5E-02	3.7E-01	1.4E-02	2.1E-04
QBOPC-10	192	0.13	112.26	2.29	18.84	0.15	n.a.	n.a.	9.4E-04	3.1E-02	4.6E-01	1.8E-02	2.3E-04
QBOPC-11	216	0.15	133.75	2.78	23.30	0.19	n.a.	n.a.	1.1E-03	3.7E-02	5.6E-01	2.2E-02	2.4E-04
QBOPC-12	240	0.19	156.58	3.32	28.10	0.25	n.a.	n.a.	1.4E-03	4.3E-02	6.6E-01	2.6E-02	2.6E-04
QBOPC-13	264	0.23	180.98	3.89	33.16	0.30	n.a.	n.a.	1.7E-03	5.0E-02	7.8E-01	3.1E-02	2.8E-04

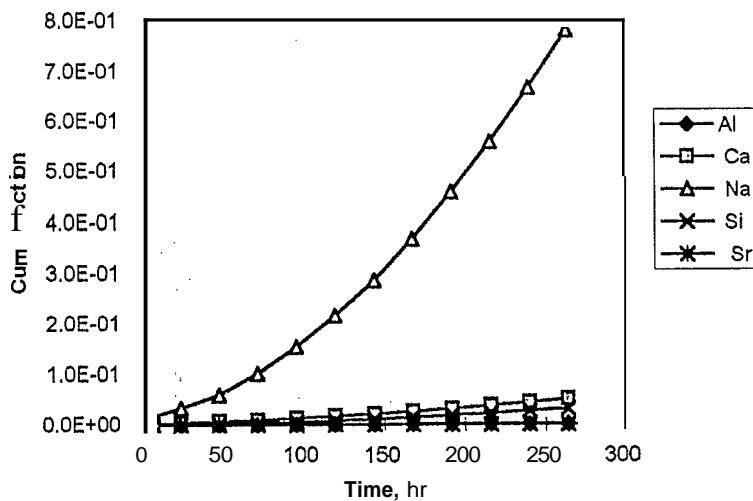
Summary

Experiment Q-BOP-C

Cum. Mass Released



Cum. Fractional Release

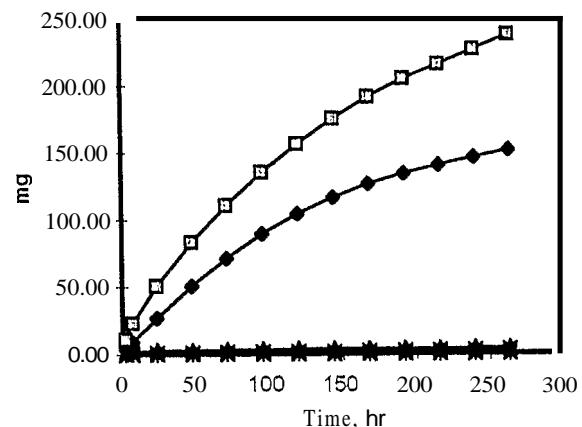
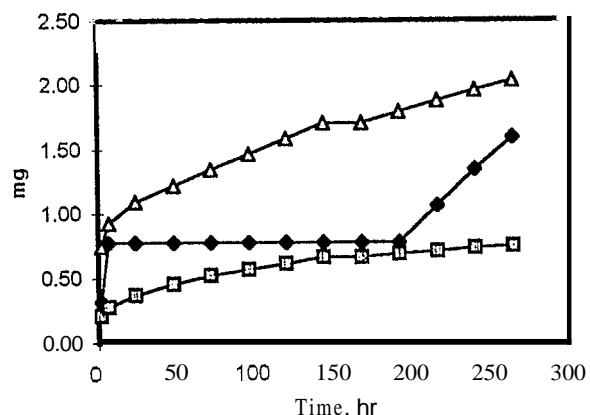
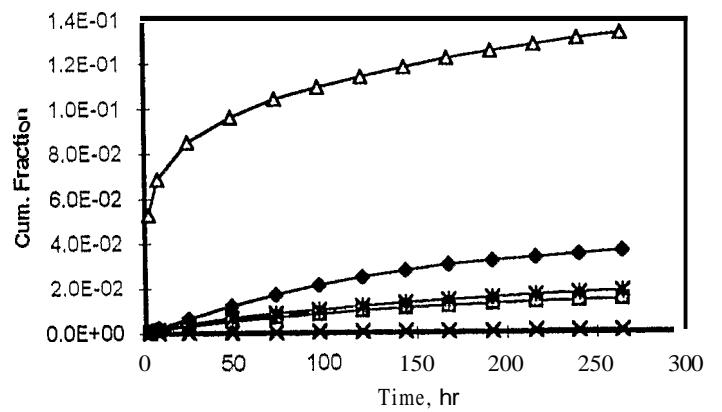


Summary

Experiment	E1														
Temp(C)	20														
material	chunk														
volume(mL)	300														
	Concentration (ppm)														
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH					
21-20-1	2	10.98	36.27	0.56	5.62	2.60	0.02	1.08	0.69	2.48	11.20				
31-20-2	7	19.85	40.24	0.15	1.70	0.65	0.04	1.52	0.24	0.61	11.40				
31-20-3	24	59.23	92.91	0.04	1.73	0.32	0.10	0.00	0.30	0.54	11.70				
31-20-4	48	79.50	107.00	0.02	1.17	0.25	0.11	0.00	0.27	0.43	11.35				
31-20-5	72	67.54	92.30	-0.01	0.88	0.27	0.08	0.00	0.22	0.41	11.30				
31-20-6	96	60.09	82.34	0.01	0.54	0.40	0.07	0.00	0.16	0.41	11.25				
31-20-7	120	50.25	70.54	0.02	0.50	0.42	0.07	0.00	0.15	0.41	11.25				
31-20-8	144	40.74	62.76	0.01	0.46	0.56	0.06	0.00	0.17	0.39	11.20				
31-20-9	168	32.95	52.39	0.00	0.41	0.55	0.05	0.00	0.00	0.00	11.15				
El-20-10	192	25.74	45.04	0.02	0.35	0.65	0.05	0.00	0.08	0.29	11.10				
El-20-11	216	21.29	36.35	0.01	0.29	0.72	0.04	0.95	0.06	0.27	11.05				
El-20-12	240	19.87	36.56	0.03	0.31	0.90	0.04	0.94	0.08	0.27	11.05				
El-20-13	264	17.57	37.55	0.01	0.27	0.85	0.04	0.83	0.05	0.25	11.00				
	Cumulative Mass Released (mg)										Cumulative Fractional Releases (cations)				
time(hrs)	Al	Ca	Na	Si	Sr		Cl(mg)	SO4(mg)			Al	Ca	Na	Si	Sr
El-20-1	2	3.29	10.88	1.69	0.78	0.01	0.32	0.21	0.75		7.9E-04	6.8E-04	5.3E-02	2.6E-04	5.8E-04
E1-20-2	7	9.25	22.95	2.19	0.97	0.02	0.78	0.28	0.93		2.2E-03	1.4E-03	6.9E-02	3.2E-04	1.5E-03
E1-20-3	24	27.02	50.83	2.72	1.07	0.05	0.78	0.37	1.09		6.4E-03	3.2E-03	8.5E-02	3.6E-04	4.0E-03
El-20-4	48	50.87	82.93	3.07	1.15	0.08	0.78	0.45	1.22		1.2E-02	5.2E-03	9.6E-02	3.8E-04	6.5E-03
El-20-5	72	71.13	110.62	3.33	1.23	0.11	0.78	0.52	1.34		1.7E-02	6.9E-03	1.0E-01	4.1E-04	8.5E-03
E1-20-6	96	89.16	135.32	3.49	1.35	0.13	0.78	0.57	1.46		2.1E-02	8.4E-03	1.1E-01	4.5E-04	1.0E-02
El-20-7	120	104.23	156.48	3.64	1.47	0.15	0.78	0.61	1.59		2.5E-02	9.7E-03	1.1E-01	4.9E-04	1.2E-02
El-20-8	144	116.45	175.31	3.78	1.64	0.17	0.78	0.66	1.70		2.8E-02	1.1E-02	1.2E-01	5.4E-04	1.3E-02
El-20-9	168	126.34	191.03	3.91	1.80	0.18	0.78	0.66	1.70		3.0E-02	1.2E-02	1.2E-01	6.0E-04	1.5E-02
El-20-10	192	134.06	204.54	4.01	2.00	0.20	0.78	0.69	1.79		3.2E-02	1.3E-02	1.3E-01	6.6E-04	1.6E-02
El-20-11	216	140.45	215.44	4.10	2.21	0.21	1.06	0.71	1.87		3.4E-02	1.3E-02	1.3E-01	7.4E-04	1.7E-02
E1-20-12	240	146.41	226.41	4.19	2.48	0.22	1.34	0.73	1.95		3.5E-02	1.4E-02	1.3E-01	8.2E-04	1.8E-02
E1-20-13	264	151.68	237.68	4.27	2.74	0.23	1.59	0.75	2.03		3.6E-02	1.5E-02	1.3E-01	9.1E-04	1.8E-02

Experiment

E1

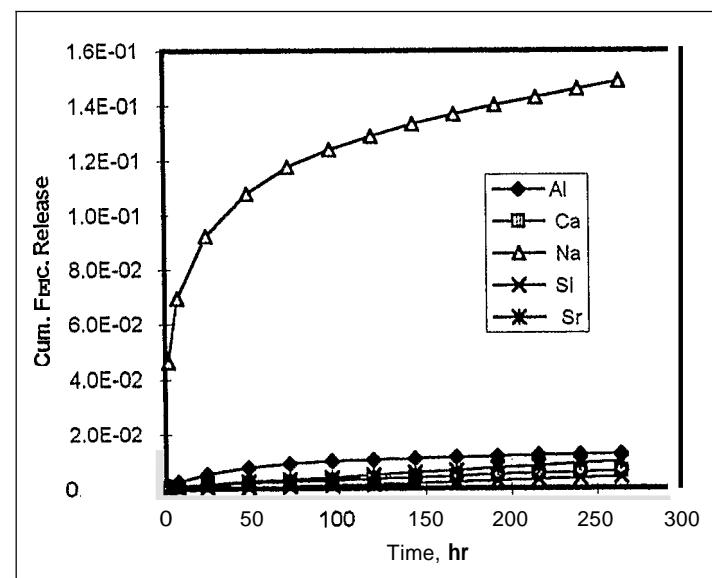
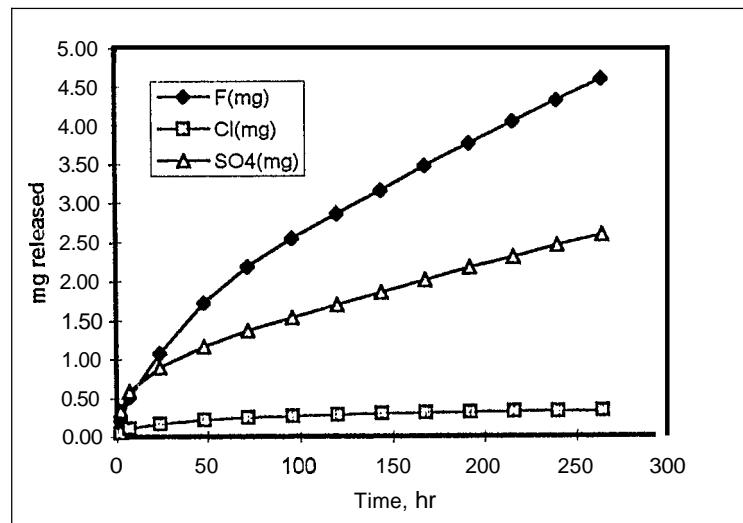
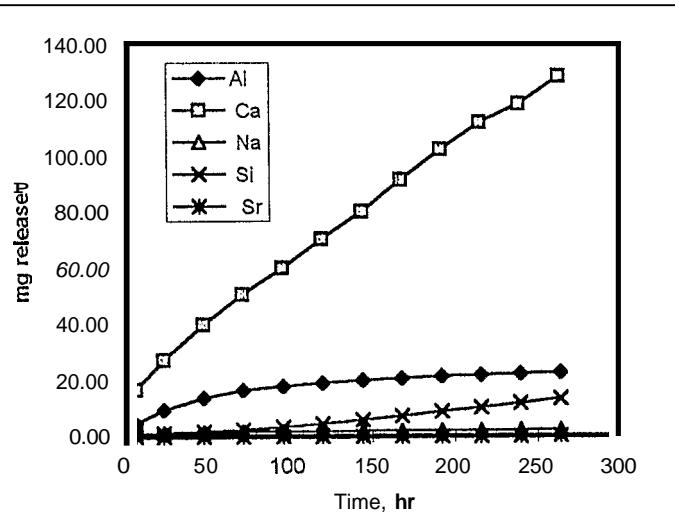
Cum. Mass Released**Cum. Mass Released****Cumulative Fraction Released**

Summary

Experiment	E2													
Temp(C)	20													
material	chunk													
volume(mL)	300													
Concentrations mg/L														
	time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH			
32-20-1	2	7.35	31.07	2.47	2.32	2.53	0.02	0.69	0.18	1.13	11.03			
32-20-2	7	8.86	25.71	0.52	1.16	0.93	0.02	1.02	0.17	0.84	11.22			
Z2-20-3	24	16.23	34.63	0.19	1.14	1.11	0.03	1.87	0.21	1.02	11.40			
Z2-20-4	48	13.97	42.29	0.15	0.77	1.60	0.04	2.13	0.17	0.88				
E2-20-5	72	9.08	35.95	0.08	0.49	2.28	0.03	1.54	0.10	0.68	11.05			
Z2-20-6	96	5.13	31.20	0.12	0.32	2.91	0.03	1.18	0.07	0.56	11.03			
E2-20-7	120	3.68	33.43	0.04	0.24	3.89	0.03	1.06	0.04	0.54	11.02			
Z2-20-8	144	2.87	32.51	0.12	0.22	4.33	0.04	1.00	0.05	0.52	11.00			
E2-20-9	168	2.38	37.15	0.01	0.18	5.08	0.04	1.06	0.03	0.54	11.10			
E2-20-10	192	1.94	36.08	0.04	0.17	4.95	0.03	0.95	0.03	0.50	11.00			
82-20-11	216	1.77	31.63	0.03	0.13	4.83	0.03	0.95	0.02	0.46	11.00			
E2-20-12	240	1.58	22.33	0.00	0.15	5.20	0.03	0.90	0.02	0.47	10.90			
E2-20-13	264	1.63	32.63	0.00	0.14	5.49	0.03	0.92	0.02	0.45	11.00			
Cumulative Mass Released (mg)										Cumulative Fractional Releases (cations)				
	time(hrs)	Al	Ca	Na	Si	Sr	F(mg)	Cl(mg)	SO4(mg)	Al	Ca	Na	Si	Sr
E2-20-1	2	2.21	9.32	0.69	0.76	0.01	0.21	0.05	0.34	1.2E-03	4.7E-04	4.6E-02	2.4E-04	4.6E-04
E2-20-2	7	4.86	17.03	1.04	1.04	0.01	0.51	0.10	0.59	2.7E-03	8.5E-04	7.0E-02	3.3E-04	8.6E-04
E2-20-3	24	9.73	27.42	1.38	1.37	0.02	1.08	0.17	0.89	5.4E-03	1.4E-03	9.2E-02	4.3E-04	1.6E-03
E2-20-4	48	13.92	40.11	1.62	1.85	0.03	1.72	0.22	1.16	7.7E-03	2.0E-03	1.1E-01	5.9E-04	2.5E-03
E2-20-5	72	16.64	50.90	1.76	2.53	0.04	2.18	0.25	1.36	9.2E-03	2.5E-03	1.2E-01	8.0E-04	3.3E-03
E2-20-6	96	18.18	60.26	1.86	3.40	0.05	2.53	0.27	1.53	1.0E-02	3.0E-03	1.2E-01	1.1E-03	4.1E-03
E2-20-7	120	19.29	70.28	1.93	4.57	0.06	2.85	0.28	1.69	1.1E-02	3.5E-03	1.3E-01	1.4E-03	4.9E-03
E2-20-8	144	20.15	80.04	2.00	5.87	0.07	3.15	0.30	1.85	1.1E-02	4.0E-03	1.3E-01	1.9E-03	5.8E-03
E2-20-9	168	20.86	91.18	2.05	7.40	0.08	3.47	0.31	2.01	1.2E-02	4.6E-03	1.4E-01	2.3E-03	6.7E-03
E2-20-10	192	21.44	102.01	2.10	8.88	0.09	3.75	0.31	2.16	1.2E-02	5.1E-03	1.4E-01	2.8E-03	7.5E-03
E2-20-11	216	21.97	111.50	2.14	10.33	0.10	4.03	0.32	2.30	1.2E-02	5.6E-03	1.4E-01	3.3E-03	8.3E-03
E2-20-12	240	22.44	118.19	2.19	11.89	0.11	4.31	0.33	2.44	1.2E-02	5.9E-03	1.5E-01	3.8E-03	9.1E-03
E2-20-13	264	22.93	127.98	2.23	13.53	0.12	4.58	0.33	2.58	1.3E-02	6.4E-03	1.5E-01	4.3E-03	9.9E-03

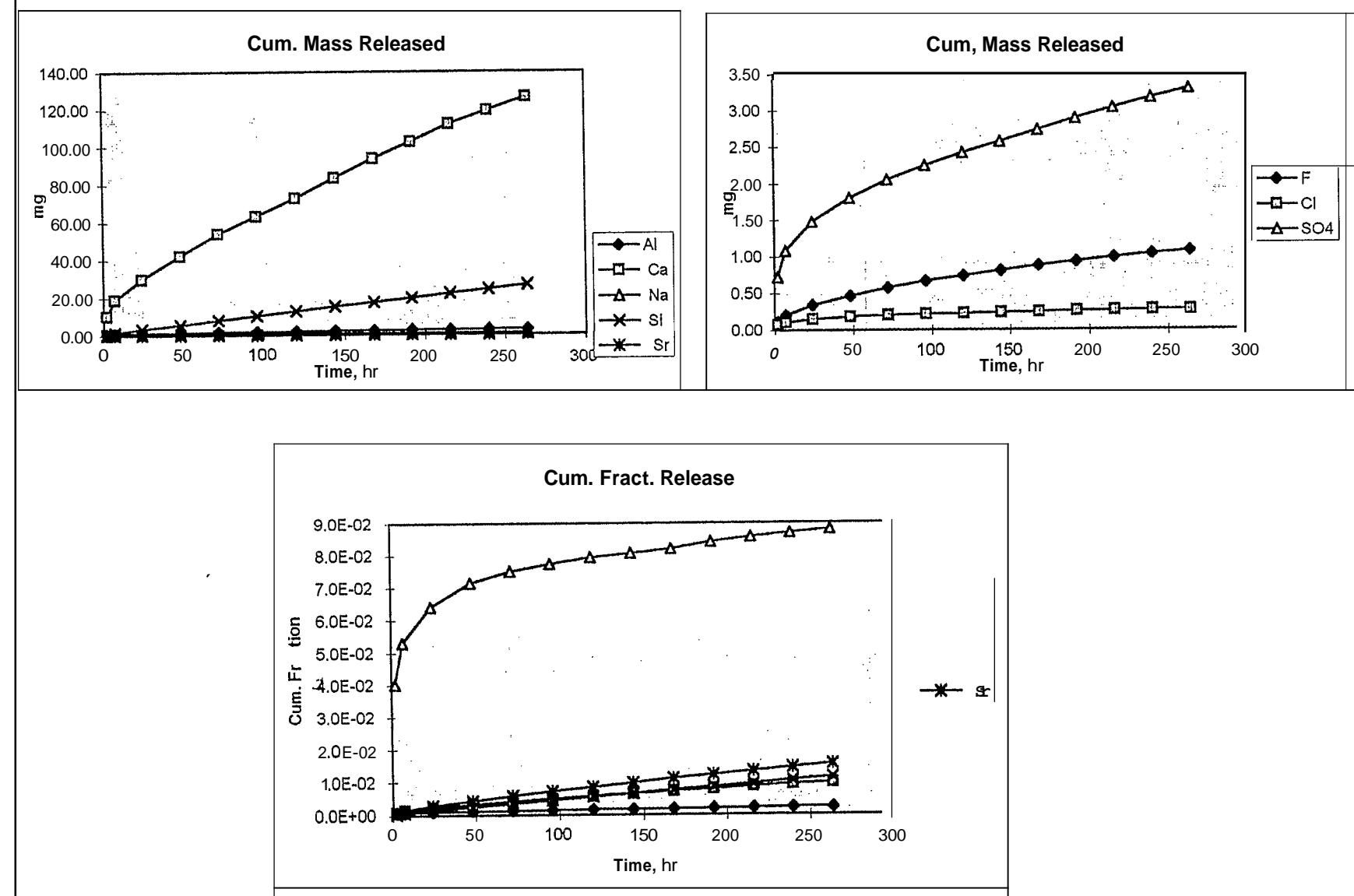
Experiment

E2



Experiment	E3												
Temp(C)	20												
material	chunk												
volume(mL)	300												
Concentration (ppm)													
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH			
33-20-1	2	2.498	34.81	1.017	1.338	2.671	0.02463	0.38	0.26	2.40	11.38		
33-20-2	7	1.044	28.98	0.1912	0.4311	2.862	0.02122	0.30	0.12	1.20	11.42		
33-20-3	24	0.9202	34.93	0.08689	0.3648	5.957	0.03674	0.46	0.14	1.34	11.50		
33-20-4	48	0.7685	41.8	0.05356	0.2466	7.529	0.04373	0.44	0.10	1.06	11.15		
33-20-5	72	0.6275	38.39	0.02717	0.1217	7.823	0.04476	0.36	0.07	0.82	11.10		
33-20-6	96	0.6174	31.91	0.00482	0.07572	7.815	0.03805	0.28	0.05	0.66	11.10		
33-20-7	120	0.5651	32.04	0.00131	0.06386	7.919	0.03483	0.25	0.04	0.57	11.10		
33-20-8	144	0.5994	35.68	0.0491	0.04535	7.964	0.0375	0.23	0.04	0.52	11.10		
33-20-9	168	0.5609	34.08	-0.00569	0.04342	7.632	0.0367	0.22	0.03	0.52	11.08		
33-20-10	192	0.5283	29.47	-0.00292	0.07138	7.411	0.03362	0.20	0.03	0.53	11.05		
E3-20-11	216	0.4989	30.89	-0.00652	0.0547	7.499	0.03148	0.18	0.02	0.47	11.00		
E3-20-12	240	0.5164	23.68	-0.00549	0.04211	7.575	0.03184	0.16	0.02	0.47			
E3-20-13	264	0.4763	24.32	-0.00939	0.03653	7.615	0.03171	0.13716	0.00951	0.40906			
Cumulative Mass Released (mg)													
time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr
E3-20-1	2	0.75	10.44	0.40	0.80	0.01	0.12	0.08	5.8E-04	8.1E-04	4.0E-02	3.5E-04	8.6E-04
E3-20-2	7	1.06	19.14	0.53	1.66	0.01	0.20	0.11	8.2E-04	1.5E-03	5.3E-02	7.2E-04	1.6E-03
E3-20-3	24	1.34	29.62	0.64	3.45	0.02	0.34	0.15	1.0E-03	2.3E-03	6.4E-02	1.5E-03	2.9E-03
E3-20-4	48	1.57	42.16	0.71	5.71	0.04	0.47	0.18	1.2E-03	3.3E-03	7.1E-02	2.5E-03	4.4E-03
E3-20-5	72	1.76	53.67	0.75	8.05	0.05	0.58	0.20	1.4E-03	4.2E-03	7.5E-02	3.5E-03	5.9E-03
E3-20-6	96	1.94	63.25	0.77	10.40	0.06	0.66	0.22	1.5E-03	4.9E-03	7.7E-02	4.5E-03	7.3E-03
E3-20-7	120	2.11	72.86	0.79	12.77	0.07	0.74	0.23	1.6E-03	5.6E-03	7.9E-02	5.5E-03	8.5E-03
E3-20-8	144	2.29	83.56	0.81	15.16	0.08	0.81	0.24	1.8E-03	6.5E-03	8.1E-02	6.6E-03	9.8E-03
E3-20-9	168	2.46	93.79	0.82	17.45	0.10	0.87	0.25	1.9E-03	7.3E-03	8.2E-02	7.6E-03	1.1E-02
E3-20-10	192	2.62	102.63	0.84	19.67	0.11	0.93	0.26	2.0E-03	8.0E-03	8.4E-02	8.5E-03	1.2E-02
E3-20-11	216	2.77	111.89	0.86	21.92	0.11	0.99	0.27	2.1E-03	8.7E-03	8.6E-02	9.5E-03	1.3E-02
E3-20-12	240	2.92	119.00	0.87	24.20	0.12	1.03	0.27	2.3E-03	9.2E-03	8.7E-02	1.0E-02	1.4E-02
E3-20-13	264	3.07	126.29	0.88	26.48	0.13	1.08	0.28	2.4E-03	9.8E-03	8.8E-02	1.1E-02	1.6E-02

Experiment E3



Experiment E1

Temp(C) 60

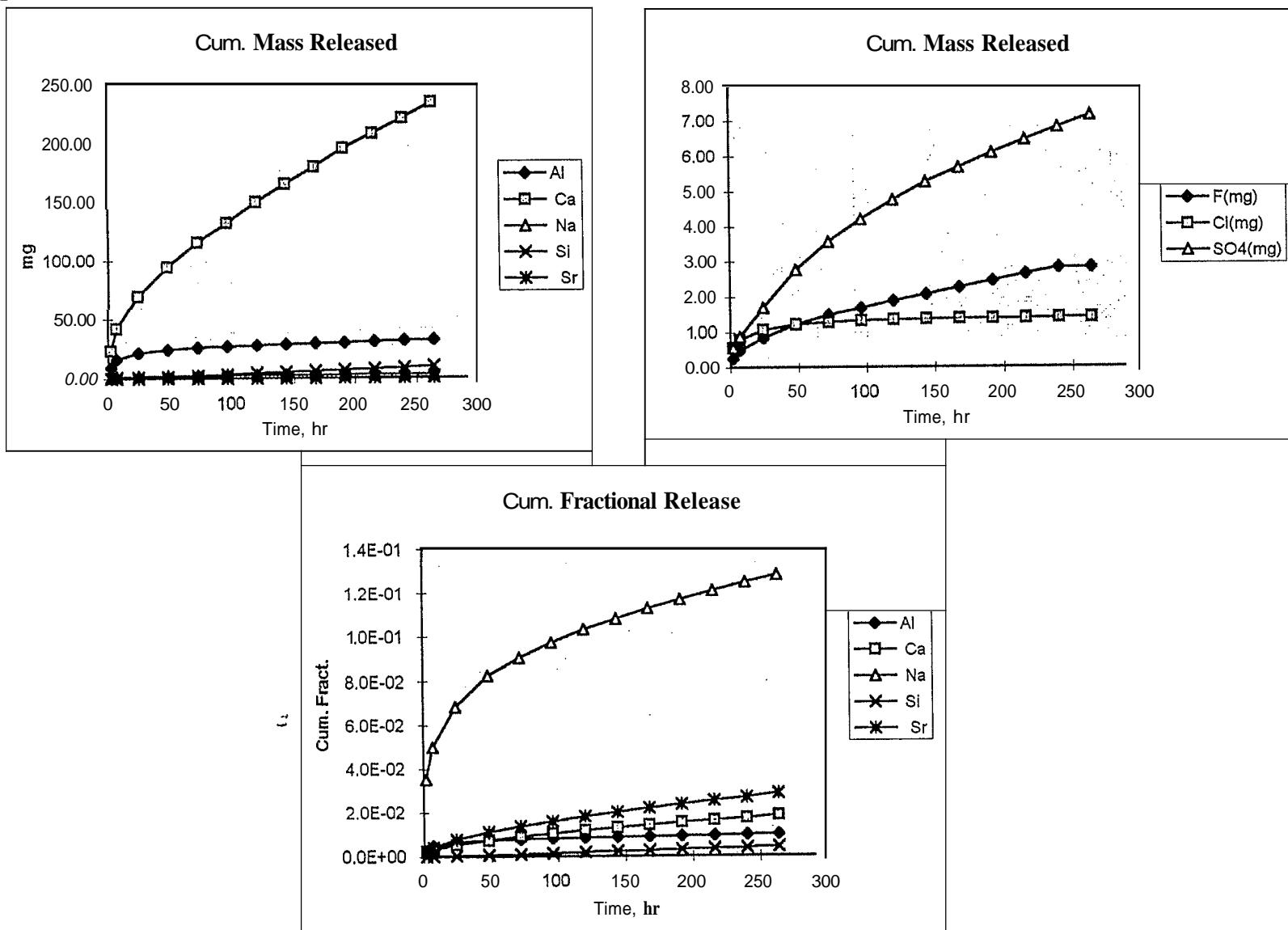
material chunk

volume(mL) 300

	Concentration (ppm)										
	time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH
E1-1	2	30.38	78.55	0.9938	2.987	1.837	0.08396	0.86	1.87	1.91	11.3
E1-2	7	23.77	62.47	0.01983	1.259	0.4343	0.06049	0.76	0.76	0.99	11.52
E1-3	24	18.31	92.05	0.01492	1.573	0.9529	0.1123	1.23	0.94	2.75	12.5
E1-4	48	8.975	81.65	-0.00158	1.167	1.76	0.109	1.23	0.48	3.59	
E1-5	72	5.401	70.2	0.001946	0.6918	2.744	0.08745	0.86	0.23	2.67	
E1-6	96	3.726	55.4	-0.00235	0.5916	3.207	0.07357	0.69	0.14	2.14	
E1-7	120	3.111	59.57	-0.0034	0.4884	3.629	0.07313	0.65	0.09	1.83	
E1-8	144	2.578	50.92	0.007021	0.4093	3.331	0.06742	0.63	0.07	1.65	12.27
E1-9	168	2.307	47.8	0.006615	0.3994	3.159	0.0588	0.62	0.01	1.37	
E1-10	192	2.631	50.49	0.000708	0.3349	3.162	0.05578	0.65	0.03	1.37	
E1-11	216	2.43	42.05	0.006997	0.3526	3.062	0.05347	0.64	0.03	1.26	
E1-12	240	2.583	43.33	0.004456	0.3125	2.935	0.05175	0.59	0.03	1.16	
E1-13	264	2.567	43.63	0.003933	0.2908	3.543	0.05893	0.06	0.03	1.18	12.15

time(hrs)	Cumulative Mass Relcascd (mg)					Cumulative Fractional Releases (cations)								
	Al	Ca	Na	Si	Sr	F(mg)	Cl(mg)	SO4(mg)	Al	Ca	Na	Si	Sr	
E1-1	2	9.11	23.57	0.90	0.55	0.03	0.26	0.56	0.57	2.7E-03	1.9E-03	3.5E-02	2.3E-04	2.5E-03
E1-2	7	16.25	42.31	1.27	0.68	0.04	0.48	0.79	0.87	4.9E-03	3.3E-03	5.0E-02	2.9E-04	4.4E-03
E1-3	24	21.74	69.92	1.75	0.97	0.08	0.85	1.07	1.69	6.6E-03	5.5E-03	6.8E-02	4.1E-04	7.8E-03
E1-4	48	24.43	94.42	2.10	1.50	0.11	1.22	1.22	2.77	7.4E-03	7.4E-03	8.2E-02	6.3E-04	1.1E-02
E1-5	72	26.05	115.48	2.30	2.32	0.14	1.48	1.28	3.57	7.9E-03	9.1E-03	9.0E-02	9.7E-04	1.4E-02
E1-6	96	27.17	132.10	2.48	3.28	0.16	1.69	1.32	4.21	8.2E-03	1.0E-02	9.7E-02	1.4E-03	1.6E-02
E1-7	120	28.10	149.97	2.63	4.37	0.18	1.88	1.35	4.76	8.5E-03	1.2E-02	1.0E-01	1.8E-03	1.8E-02
E1-8	144	28.88	165.24	2.75	5.37	0.20	2.07	1.37	5.26	8.7E-03	1.3E-02	1.1E-01	2.3E-03	2.0E-02
E1-9	168	29.57	179.58	2.87	6.32	0.22	2.26	1.38	5.67	8.9E-03	1.4E-02	1.1E-01	2.7E-03	2.2E-02
E1-10	192	30.36	194.73	2.97	7.26	0.23	2.45	1.39	6.08	9.2E-03	1.5E-02	1.2E-01	3.18E-03	2.4E-02
E1-11	216	31.09	207.35	3.08	8.18	0.25	2.65	1.40	6.46	9.4E-03	1.6E-02	1.2E-01	3.4E-03	2.5E-02
E1-12	240	31.86	220.34	3.17	9.06	0.27	2.82	1.41	6.81	9.6E-03	1.7E-02	1.2E-01	3.8E-03	2.7E-02
E1-13	264	32.63	233.43	3.26	10.13	0.28	2.84	1.42	7.16	9.8E-03	1.8E-02	1.3E-01	4.38E-03	2.9E-02

Experiment E1



Summary

Experiment E2

Temp(C) 60

material chunk

volume(mL) 300

Concentration (ppm)

	time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH
32-1	2	6.399	13.870	0.002	1.452	1.356	0.016	0.44	0.42	3.06	
32-2	7	2.298	14.820	-0.001	0.212	2.209	0.021	0.24	0.16	1.47	
32-3	24	2.160	37.500	-0.003	0.183	7.630	0.056	0.42	0.21	1.49	
32-4	48	1.582	40.680	-0.003	0.171	8.677	0.064	0.33	0.14	1.53	
32-5	72	1.407	39.280	-0.005	0.113	8.717	0.061	0.26	0.08	1.07	
32-6	96	1.459	40.030	-0.004	0.089	8.238	0.053	0.23	0.06	0.78	
Z2-7	120	1.217	36.250	0.001	0.064	7.724	0.048	0.19	0.05	0.77	
32-8	144	1.106	33.250	-0.005	0.072	7.678	0.050	0.20	0.06	0.74	
Z2-9	168	1.105	33.340	-0.007	0.041	7.347	0.048	0.19	0.04	0.70	
E2-10	192	1.021	29.960	-0.004	0.060	7.037	0.044	0.19	0.03	0.63	
32-11	216	1.218	32.480	-0.005	0.040	7.272	0.042	0.19	0.05	0.67	
E2-12	240	1.137	31.120	-0.010	0.050	6.758	0.039	0.19	0.07	0.59	
E2-13	264	1.253	32.280	-0.010	0.053	6.159	0.037	0.19	0.05	0.59	

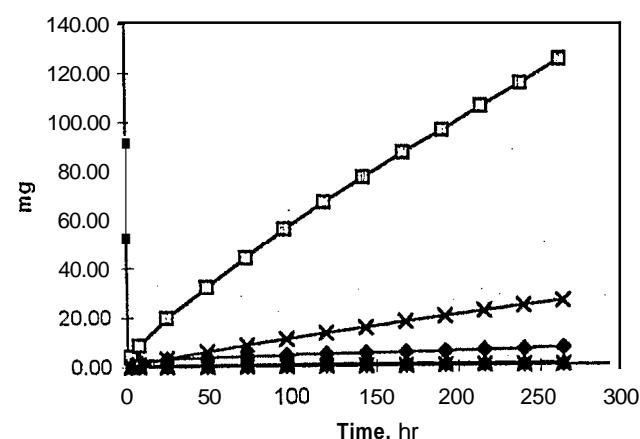
Cumulative Mass Released (mg)

time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Cumulative Fractional Releases (cations)					
									Al	Ca	Na	Si	Sr	
E2-1	2	1.92	4.16	0.44	0.41	0.00	0.13	0.12	0.92	1.4E-03	2.7E-04	3.7E-02	1.6E-04	5.0E-04
E2-2	7	2.61	8.61	0.50	1.07	0.01	0.20	0.17	1.36	1.8E-03	5.5E-04	4.3E-02	4.3E-04	1.2E-03
E2-3	24	3.26	J9.86	0.55	3.36	0.03	0.33	0.24	1.81	2.3E-03	1.3E-03	4.7E-02	1.4E-03	2.9E-03
E2-4	48	3.73	32.06	0.61	5.96	0.05	0.43	0.28	2.27	2.6E-03	2.1E-03	5.2E-02	2.4E-03	4.9E-03
E2-5	72	4.15	43.85	0.64	8.58	0.07	0.51	0.30	2.59	2.9E-03	2.8E-03	5.5E-02	3.5E-03	6.8E-03
E2-6	96	4.59	55.85	0.67	11.05	0.08	0.57	0.32	2.82	3.2E-03	3.6E-03	5.7E-02	4.5E-03	8.5E-03
E2-7	120	4.96	66.73	0.68	13.37	0.10	0.63	0.34	3.05	3.5E-03	4.3E-03	5.9E-02	5.4E-03	1.0E-02
E2-8	144	5.29	76.70	0.71	15.67	0.11	0.69	0.36	3.27	3.7E-03	4.9E-03	6.0E-02	6.3E-03	1.2E-02
E2-9	168	5.62	86.71	0.72	17.87	0.13	0.75	0.37	3.48	4.0E-03	5.6E-03	6.1E-02	7.2E-03	1.3E-02
E2-10	192	5.93	95.69	0.74	19.98	0.14	0.81	0.38	3.67	4.2E-03	6.1E-03	6.3E-02	8.1E-03	1.4E-02
B2-11	216	6.29	105.44	0.75	22.17	0.15	0.87	0.39	3.87	4.5E-03	6.8E-03	6.4E-02	9.0E-03	1.6E-02
E2-12	240	6.63	114.77	0.76	24.19	0.16	0.92	0.42	4.05	4.7E-03	7.4E-03	6.5E-02	9.8E-03	1.7E-02
E2-13	264	7.01	124.46	0.78	26.04	0.17	0.98	0.43	4.23	5.0E-03	8.0E-03	6.7E-02	1.1E-02	1.8E-02

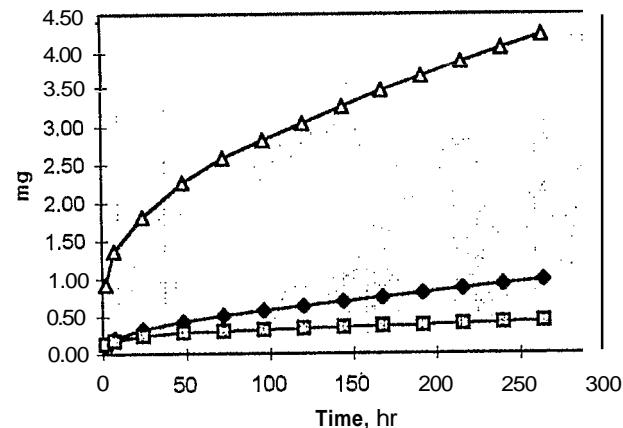
Summary

Experiment E2

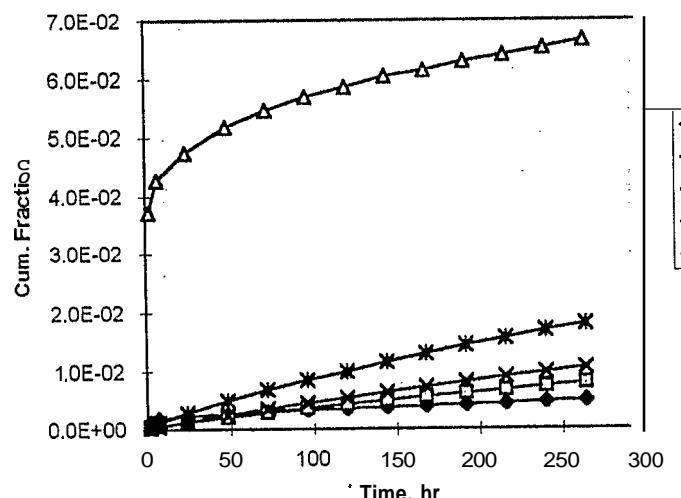
Cum. Mass Released



Cum. Mass Released



Cum. Fractional Release



Summary

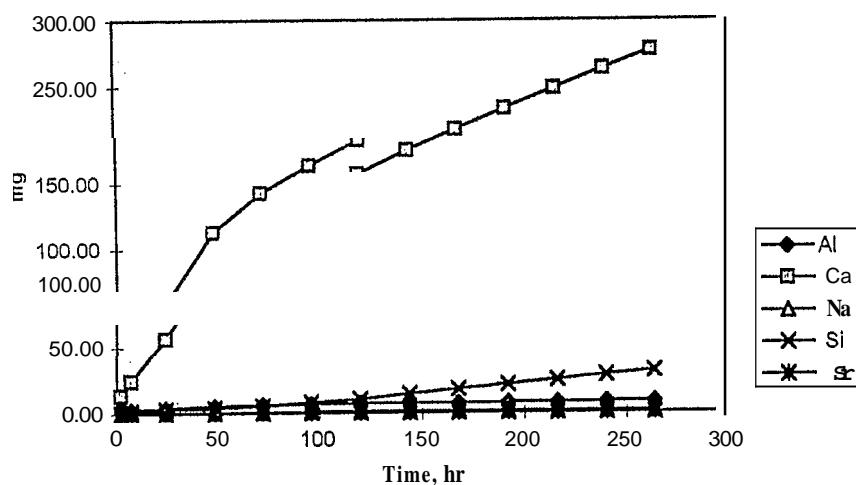
Experiment	E3													
Temp(C)	60													
material	chunk													
volume(mL)	300													
	Concentration (ppm)													
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH				
33-1	2	7.09	45.07	0.57	1.61	2.81	0.03	0.53	0.60	6.38	11.88			
33-2	7	3.26	35.10	0.03	0.26	3.81	0.07	0.00	0.80	0.88	11.22			
33-3	24	3.35	108.40	0.20	0.26	5.32	0.09	0.00	0.28	3.81	12.49			
E3-4	48	4.52	187.10	-0.01	0.15	1.84	0.07	0.00	0.29	4.29				
E3-5	72	3.19	99.00	-0.01	0.09	4.84	0.05	0.32	0.11	2.50				
E3-6	96	1.36	72.04	-0.01	0.11	7.11	0.05	0.22	0.03	1.23				
E3-7	120	1.07	64.75	0.04	0.53	9.37	0.06	0.33	0.71	0.87				
E3-8	144	0.79	61.07	0.01	0.15	11.98	0.06	0.17	0.13	0.63	12.22			
E3-9	168	0.71	52.61	-0.01	0.14	11.62	0.06	0.15	0.06	0.58				
E3-10	192	0.68	51.56	-0.01	0.11	11.55	0.06	0.14	0.03	0.56				
E3-11	216	0.73	51.41	0.00	0.10	11.14	0.06	0.14	0.02	0.53				
E3-12	240	0.66	49.67	0.00	0.11	11.57	0.06	0.14	0.05	0.50				
E3-13	264	0.70	44.76	0.02	0.18	10.13	0.05	0.15	0.11	0.49	11.83			
	Cumulative Mass Released (mg)					Cumulative Fractional Releases (cations)								
time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr	
E3-1	2	2.13	13.52	0.48	0.84	0.01	0.16	0.18	1.91	2.0E-03	1.3E-03	5.9E-02	4.5E-04	1.4E-03
E3-2	7	3.11	24.05	0.56	1.99	0.03	0.16	0.42	2.18	3.0E-03	2.3E-03	6.8E-02	1.1E-03	4.2E-03
E3-3	24	4.11	56.57	0.64	3.58	0.06	0.16	0.51	3.32	3.9E-03	5.4E-03	7.8E-02	1.9E-03	7.9E-03
E3-4	48	5.47	12.70	0.68	4.14	0.08	0.16	0.59	4.61	5.2E-03	1.1E-02	8.3E-02	2.2E-03	1.1E-02
E3-5	72	6.42	142.40	0.71	5.59	0.09	0.26	0.63	5.36	6.1E-03	1.4E-02	8.6E-02	3.0E-03	1.3E-02
E3-6	96	6.83	164.01	0.74	7.72	0.11	0.32	0.64	5.73	6.5E-03	1.6E-02	9.0E-02	4.1E-03	1.5E-02
E3-7	120	7.15	183.44	0.90	10.53	0.13	0.42	0.85	5.99	6.8E-03	1.8E-02	1.1E-01	5.6E-03	1.8E-02
E3-8	144	7.39	201.76	0.94	14.13	0.14	0.47	0.89	6.18	7.0E-03	1.9E-02	1.2E-01	7.6E-03	2.1E-02
E3-9	168	7.60	217.54	0.99	17.61	0.16	0.52	0.90	6.36	7.2E-03	2.1E-02	1.2E-01	9.4E-03	2.3E-02
E3-10	I92	7.81	233.01	1.02	21.08	0.18	0.56	0.91	6.52	7.4E-03	2.2E-02	1.2E-01	1.1E-02	2.6E-02
E3-11	216	8.03	248.43	1.05	24.42	0.20	0.60	0.92	6.68	7.7E-03	2.4E-02	1.3E-01	1.3E-02	2.8E-02
E3-12	240	8.22	263.33	1.08	27.89	0.22	0.64	0.94	6.83	7.8E-03	2.5E-02	1.3E-01	1.5E-02	3.1E-02
E3-13	264	8.43	276.76	1.13	30.93	0.23	0.69	0.97	6.98	8.0E-03	2.7E-02	1.4E-01	1.7E-02	3.3E-02

Summary

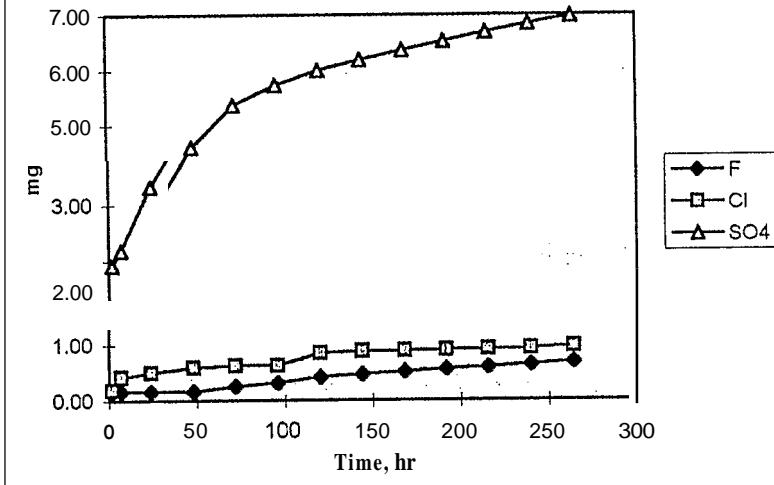
periment

E3

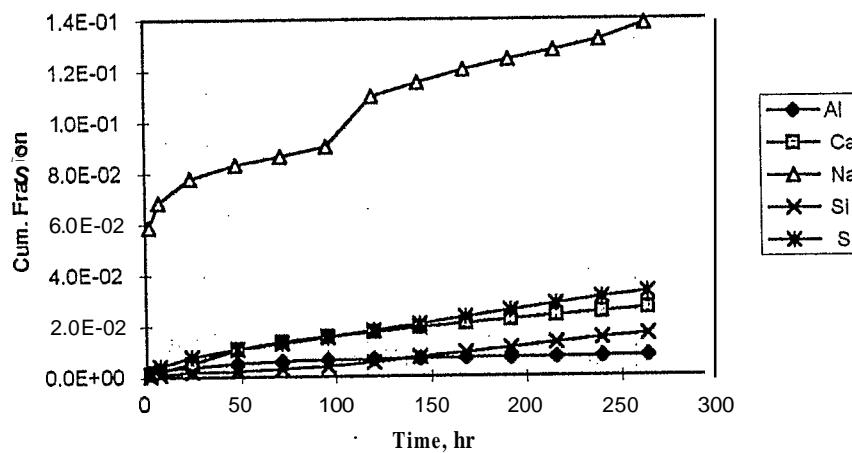
Cum. Mass Released



Cum. Mass Released



Cum. Fractional Release



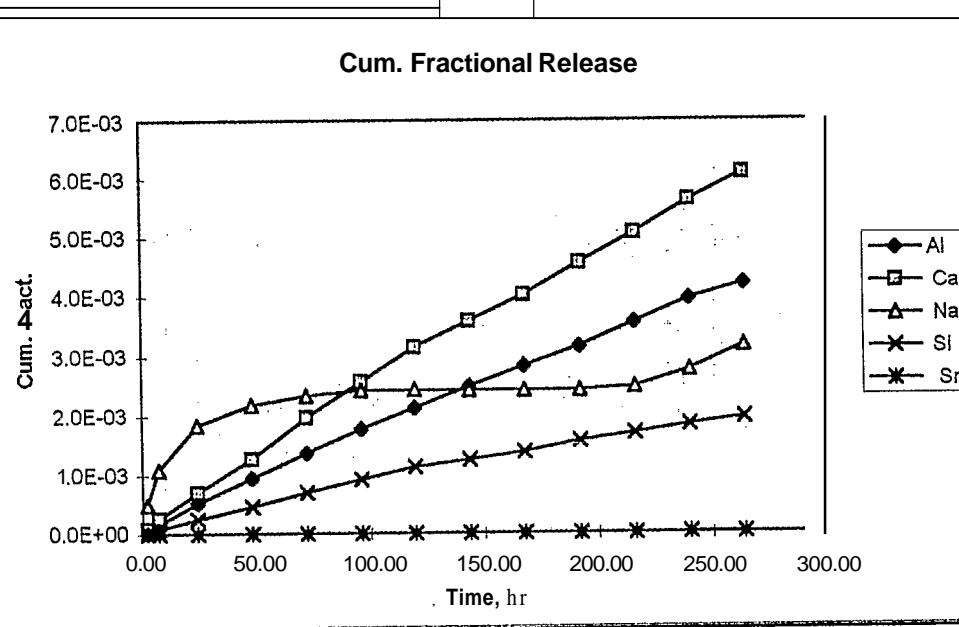
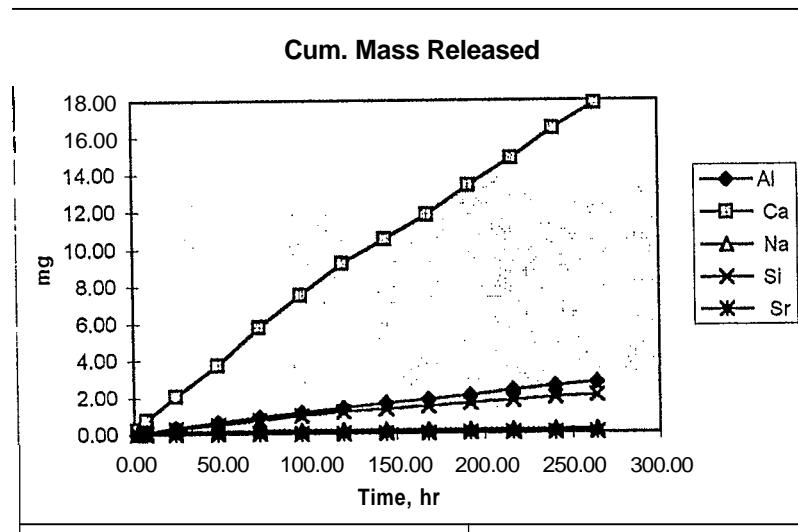
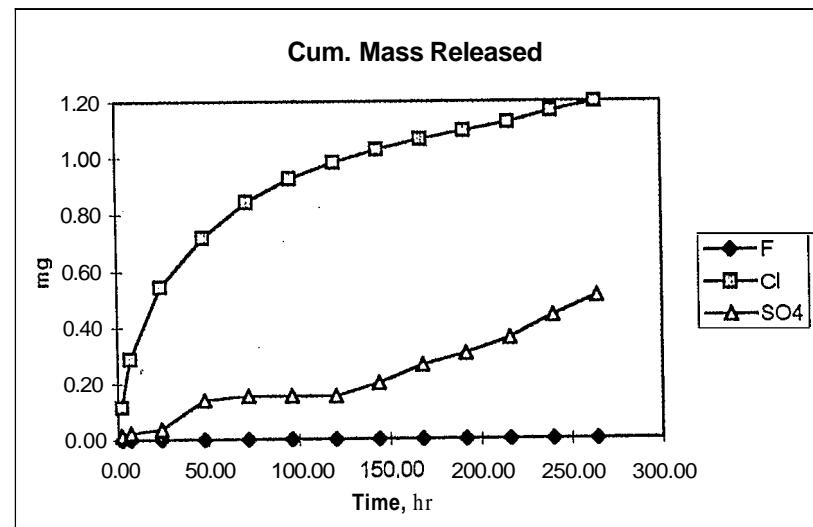
Summary

Experiment	AS001													
Temp(C)	20.00													
material	powder in membrane													
volume(mL)	200.00													
		Concentration (ppm)												
	time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH			
AS001-1	2.00	0.08	1.25	-0.03	0.17	0.20	0.00	0.00	0.58	0.07	9.10			
AS001-2	7.00	0.48	2.55	-0.02	0.21	0.29	0.00	0.00	0.86	0.05	9.55			
AS001-3	24.00	1.15	6.51	-0.02	0.27	0.85	0.01	0.00	1.29	0.06	9.60			
AS001-4	48.00	1.36	8.39	-0.02	0.12	1.07	0.01	0.00	0.87	0.53	9.70			
AS001-5	72.00	1.42	10.21	-0.03	0.05	1.28	0.01	0.00	0.62	0.07	9.80			
AS001-6	96.00	1.30	8.71	-0.02	0.03	1.12	0.01	0.00	0.41	0.00	9.80			
AS001-7	120.00	1.17	8.54	-0.03	0.00	1.09	0.01	0.00	0.29	0.00	9.10			
AS001-8	144.00	1.17	6.46	-0.02	0.00	0.68	0.01	0.00	0.23	0.23	9.20			
AS001-9	168.00	1.12	6.38	-0.02	0.00	0.67	0.01	0.00	0.18	0.32	9.20			
AS001-10	192.00	1.09	7.86	-0.02	0.00	0.95	0.01	0.00	0.15	0.21				
AS001-11	216.00	1.32	7.34	-0.03	0.02	0.72	0.01	0.00	0.15	0.27	9.50			
AS001-12	240.00	1.30	8.23	-0.03	0.10	0.75	0.01	0.00	0.20	0.41	9.22			
AS001-13	264.00	0.82	6.73	-0.03	0.14	0.64	0.01	0.00	0.17	0.34	9.52			
		Cumulative Mass Released (mg)									Cumulative Fractional Releases (cations)			
	time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr
AS001-1	2.00	0.02	0.25	0.03	0.04	0.00	0.00	0.12	0.01	2.4E-05	8.5E-05	4.9E-04	3.8E-05	7.1E-05
AS001-2	7.00	0.11	0.76	0.08	0.10	0.00	0.00	0.29	0.02	1.7E-04	2.6E-04	1.1E-03	9.2E-05	2.9E-05
AS001-3	24.00	0.34	2.06	0.13	0.27	0.00	0.00	0.54	0.04	5.2E-04	7.0E-04	1.8E-03	2.5E-04	9.1E-05
AS001-4	48.00	0.61	3.74	0.15	0.48	0.01	0.00	0.72	0.14	9.4E-04	1.3E-03	2.2E-03	4.6E-04	1.7E-05
AS001-5	72.00	0.90	5.78	0.16	0.74	0.01	0.00	0.84	0.15	1.4E-03	2.0E-03	2.3E-03	7.0E-04	2.5E-05
AS001-6	96.00	1.16	7.52	0.17	0.96	0.01	0.00	0.92	0.15	1.8E-03	2.6E-03	2.4E-03	9.2E-04	3.1E-05
AS001-7	120.00	1.39	9.23	0.17	1.18	0.01	0.00	0.98	0.15	2.1E-03	3.2E-03	2.4E-03	1.1E-03	3.6E-05
AS001-8	144.00	1.63	10.52	0.17	1.32	0.01	0.00	1.03	0.20	2.5E-03	3.6E-03	2.4E-03	1.3E-03	4.0E-05
AS001-9	168.00	1.85	11.80	0.17	1.45	0.02	0.00	1.06	0.26	2.8E-03	4.0E-03	2.4E-03	1.4E-03	4.5E-05
AS001-10	192.00	2.07	13.37	0.17	1.64	0.02	0.00	1.09	0.31	3.2E-03	4.6E-03	2.4E-03	1.6E-03	4.9E-05
AS001-11	216.00	2.33	14.84	0.17	1.79	0.02	0.00	1.12	0.36	3.6E-03	5.1E-03	2.5E-03	1.7E-03	5.4E-05
AS001-12	240.00	2.59	16.49	0.19	1.94	0.02	0.00	1.16	0.44	4.0E-03	5.6E-03	2.8E-03	1.8E-03	5.8E-05
AS001-13	264.00	2.75	17.83	0.22	2.07	0.02	0.00	1.20	0.51	4.2E-03	6.1E-03	3.2E-03	2.0E-03	6.2E-05

Summary

Experiment

AS001

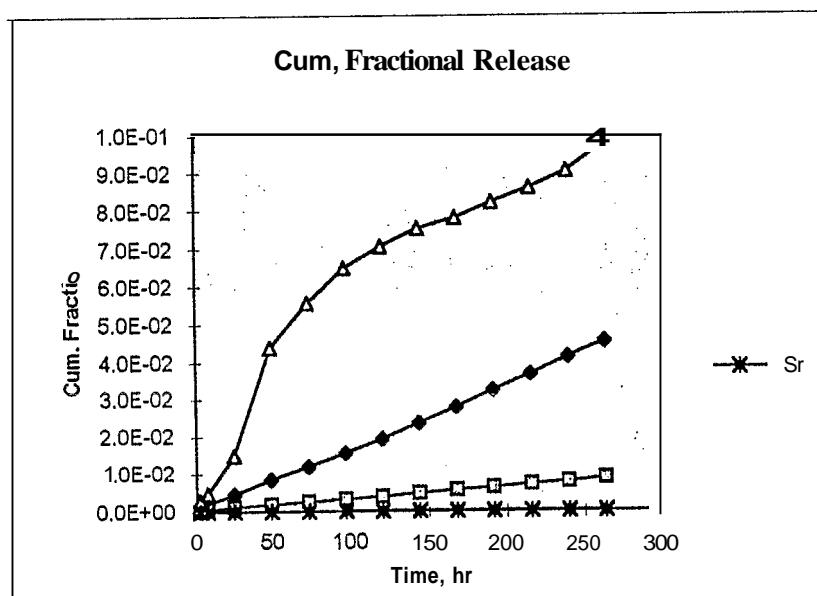
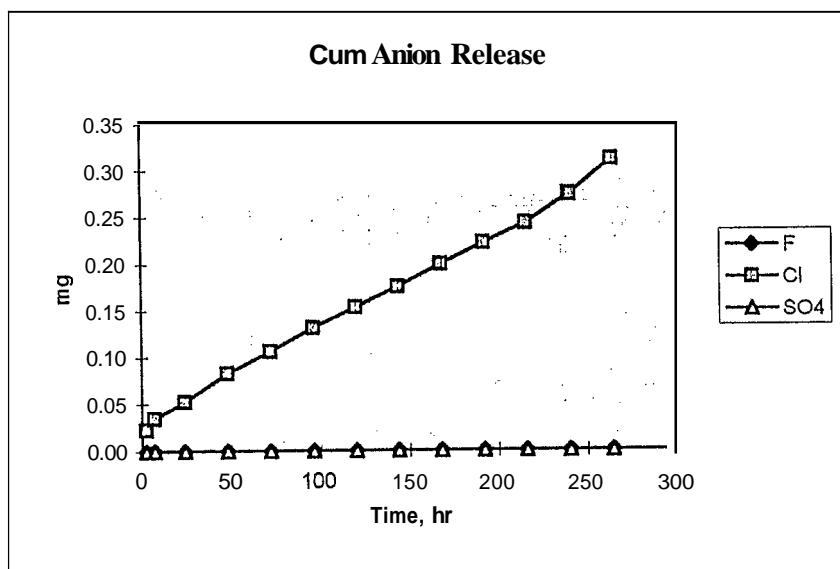
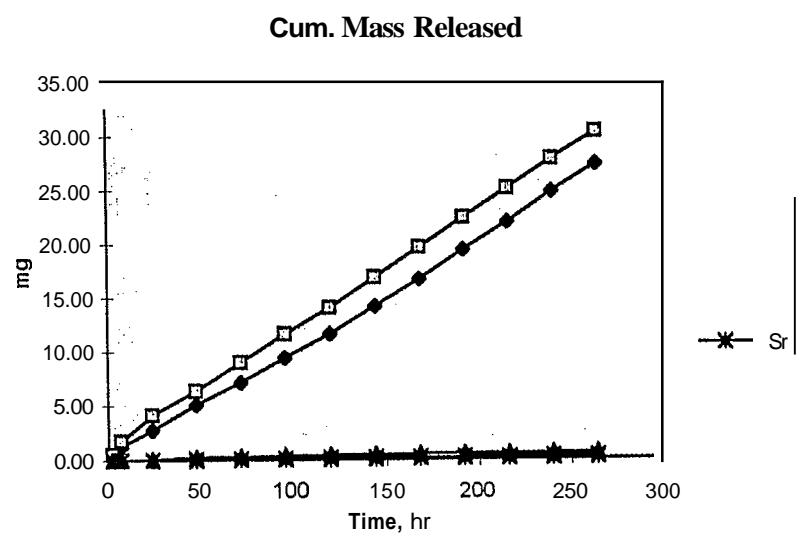


Summary

Experiment	AS002												
Temp(C)	20												
material	powder in membrane												
volume(mL)	200												
Concentration (ppm)													
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH			
AS002-1	2	1.74	2.60	-0.01	0.09	0.00	0.00	0.11	0.00	9.05			
AS002-2	7	4.60	6.17	-0.02	0.05	0.02	0.00	0.06	0.00	9.62			
AS002-3	24	7.49	11.70	-0.03	0.29	0.05	0.02	0.09	0.00	9.50			
AS002-4	48	11.52	11.16	-0.03	0.84	0.11	0.08	0.15	0.00	10.10			
AS002-5	72	10.29	13.22	-0.03	0.34	0.11	0.08	0.12	0.00	10.13			
AS002-6	96	11.16	13.03	-0.02	0.27	0.13	0.08	0.13	0.00	10.38			
AS002-7	120	11.15	12.44	-0.03	0.16	0.07	0.09	0.11	0.00	9.60			
AS002-8	144	12.95	13.92	-0.01	0.14	0.11	0.07	0.11	0.00	9.70			
AS002-9	168	12.50	13.87	0.00	0.08	0.11	0.08	0.12	0.00	9.90			
AS002-10	192	13.72	13.93	-0.03	0.12	0.11	0.08	0.11	0.00				
AS002-11	216	12.86	13.29	-0.02	0.11	0.11	0.06	0.10	0.00	9.95			
AS002-12	240	13.90	13.42	-0.02	0.13	0.11	0.07	0.15	0.00	10.22			
AS002-13	264	12.52	12.58	-0.02	0.21	0.10	0.05	0.18	0.00	10.32			
Cumulative Mass Released (mg)													
time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr
AS002-1	2	0.35	0.52	0.02	0.00	0.00	0.02	0.00	5.8E-04	1.5E-04	3.1E-03	9.5E-07	1.1E-07
AS002-2	7	1.27	1.75	0.03	0.00	0.00	0.03	0.00	2.1E-03	5.0E-04	4.9E-03	4.2E-06	3.98E-07
AS002-3	24	2.77	4.09	0.09	0.01	0.00	0.05	0.00	4.6E-03	1.2E-03	1.5E-02	1.5E-05	1.5E-06
AS002-4	48	5.07	6.32	0.25	0.04	0.02	0.08	0.00	8.5E-03	1.8E-03	4.4E-02	3.6E-05	6.3E-06
AS002-5	72	7.13	8.97	0.32	0.06	0.04	0.11	0.00	1.2E-02	2.6E-03	5.6E-02	5.9E-05	1.1E-05
AS002-6	96	9.36	11.57	0.38	0.09	0.05	0.13	0.00	1.6E-02	3.3E-03	6.5E-02	8.6E-05	1.6E-05
AS002-7	120	11.59	14.06	0.41	0.10	0.07	0.15	0.00	1.9E-02	4.0E-03	7.0E-02	1.0E-04	2.2E-05
AS002-8	144	14.18	16.85	0.44	0.12	0.09	0.18	0.00	2.4E-02	4.8E-03	7.5E-02	1.2E-04	2.6E-05
AS002-9	168	16.68	19.62	0.45	0.14	0.10	0.20	0.00	2.8E-02	5.6E-03	7.8E-02	1.4E-04	3.1E-05
AS002-10	192	19.42	22.41	0.48	0.17	0.12	0.22	0.00	3.2E-02	6.4E-03	8.2E-02	1.7E-04	3.6E-05
AS002-11	216	22.00	25.06	0.50	0.19	0.13	0.24	0.00	3.7E-02	7.1E-03	8.6E-02	1.9E-04	4.0E-05
AS002-12	240	24.78	27.75	0.52	0.21	0.14	0.27	0.00	4.1E-02	7.9E-03	9.0E-02	2.1E-04	4.4E-05
AS002-13	264	27.28	30.26	0.57	0.23	0.15	0.31	0.00	4.5E-02	8.6E-03	9.7E-02	2.3E-04	4.7E-05

Summary

Experiment AS002



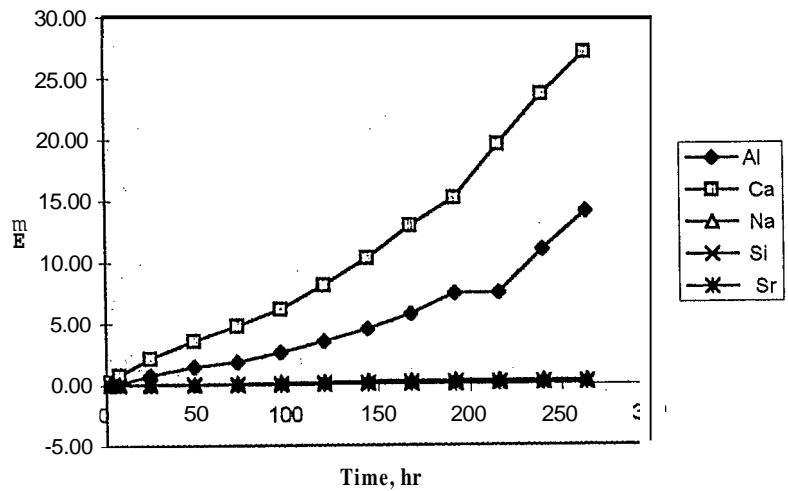
Summary

Experiment	AS003										
Temp(C)	20										
material	powder in membrane										
volume(mL)	200										
Concentration (ppm)											
time(hrs)	Al	Cn	Fe	Nn	Si	Sr	F	Cl	SO4	pH	
AS003-1	2	-0.02	1.18	0.00	0.22	-0.03	0.00	0.06	0.69	0.31	8.45
AS003-2	7	0.61	2.73	0.00	0.02	0.04	0.00	0.00	0.14	0.00	
AS003-3	24	3.20	6.96	-0.01	0.05	0.05	0.01	0.00	0.02	0.06	8.85
AS003-4	48	3.60	6.86	0.01	0.06	0.05	0.01	0.00	0.00	0.06	9.05
AS003-5	72	1.77	6.21	-0.01	0.13	0.06	0.01	0.00	0.10	0.00	8.70
AS003-6	96	3.83	6.76	0.00	0.19	0.08	0.02	0.00	0.01	0.00	9.20
AS003-7	120	4.59	9.65	0.01	0.38	0.15	0.04	0.00	0.14	0.10	9.45
AS003-8	144	5.05	11.08	0.00	0.20	0.16	0.06	0.00	0.10	0.27	9.68
AS003-9	168	6.08	13.09	0.00	0.13	0.09	0.08	0.00	0.02	0.25	9.20
AS003-10	192	8.30	11.42	-0.01	0.02	0.08	0.12	0.00	0.03	0.18	9.55
AS003-11	216	0.32	21.76	0.00	0.03	0.0s	0.16	0.11	0.14	0.08	
AS003-12	240	17.47	20.26	-0.01	0.02	0.07	0.14	0.06	0.11	0.04	
AS003-13	264	15.54	17.05	-0.01	0.01	0.07	0.09	0.06	0.10	0.06	10.50
Cumulative Mass Released (mg)											
time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Cumulative Fractional Releases (cations)		
AS003-1	2	0.00	0.24	0.0	-0.01	0.00	0.0	0.14	0.06	-5.1E-06	6.6E-05
AS003-2	7	0.12	0.78	0.05	0.00	0.00	0.01	0.17	0.06	2.0E-04	2.2E-04
AS003-3	24	0.76	2.17	0.06	0.01	0.00	0.01	0.17	0.07	1.3E-03	6.1E-04
AS003-4	48	1.48	3.55	0.07	0.02	0.00	0.01	0.17	0.09	2.5E-03	9.9E-04
AS003-5	72	1.83	4.79	0.10	0.03	0.01	0.01	0.19	0.09	3.1E-03	1.3E-03
AS003-6	96	2.60	6.14	0.13	0.05	0.01	0.01	0.19	0.09	4.3E-03	1.7E-03
AS003-7	120	3.52	8.07	0.21	0.08	0.02	0.01	0.22	0.11	5.9E-03	2.3E-03
AS003-8	144	4.53	10.29	0.25	0.11	0.03	0.01	0.24	0.16	7.5E-03	2.9E-03
AS003-9	168	5.74	12.90	0.28	0.13	0.05	0.01	0.24	0.21	9.6E-03	3.6E-03
AS003-10	192	7.40	15.19	0.28	0.15	0.07	0.01	0.25	0.25	1.2E-02	4.3E-03
AS003-11	216	7.47	19.54	0.29	0.16	0.10	0.03	0.28	0.26	1.2E-02	5.5E-03
AS003-12	240	10.96	23.59	0.29	0.17	0.13	0.05	0.30	0.27	1.8E-02	6.6E-03
AS003-13	264	14.07	27.00	0.29	0.19	0.15	0.06	0.32	0.28	2.3E-02	7.6E-03

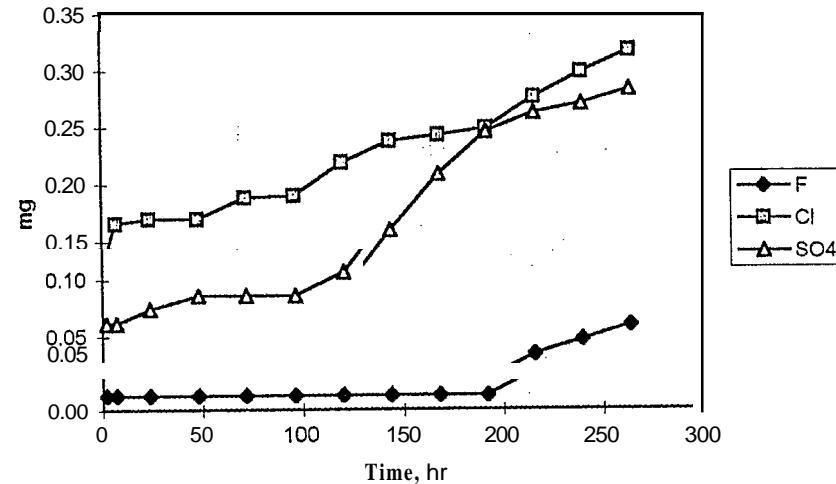
Summary

Experiment AS003

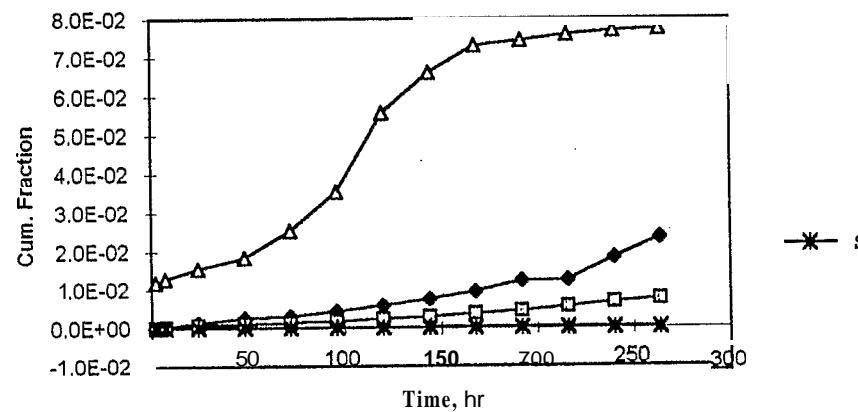
Cum. Mass Released



Cum. Mass Released



Cum. Fractional Release

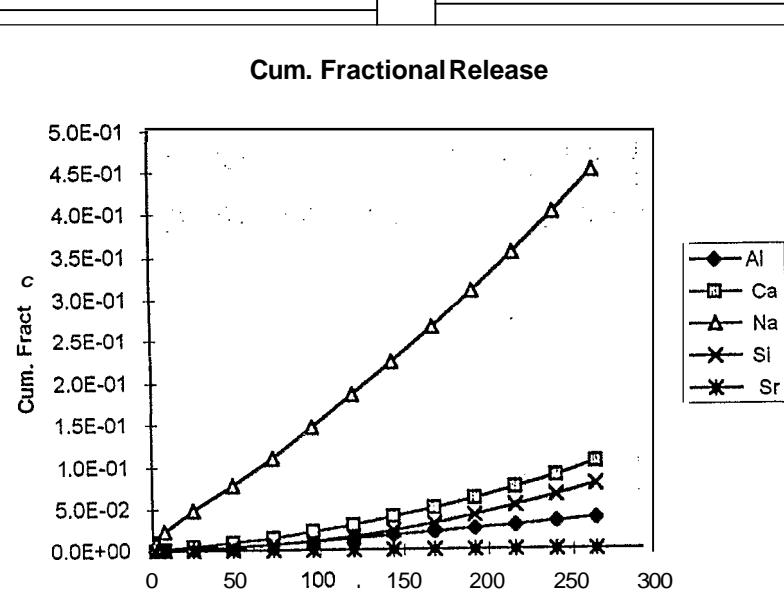
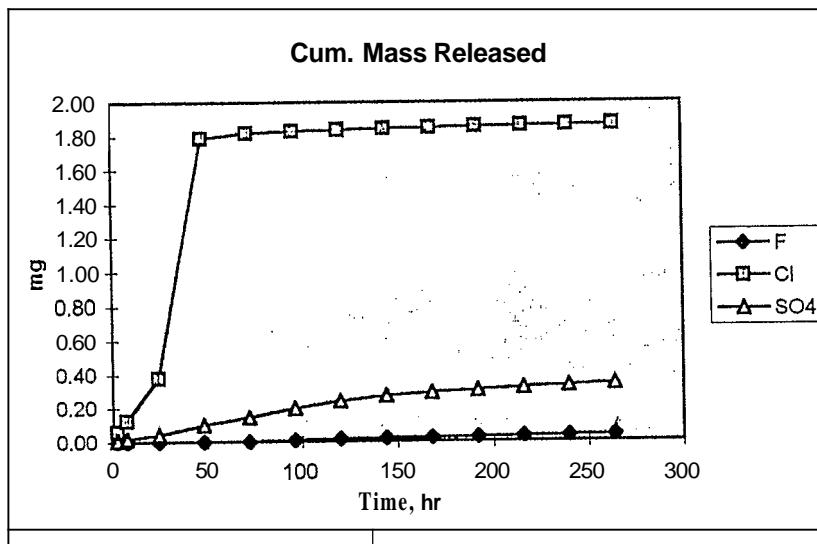
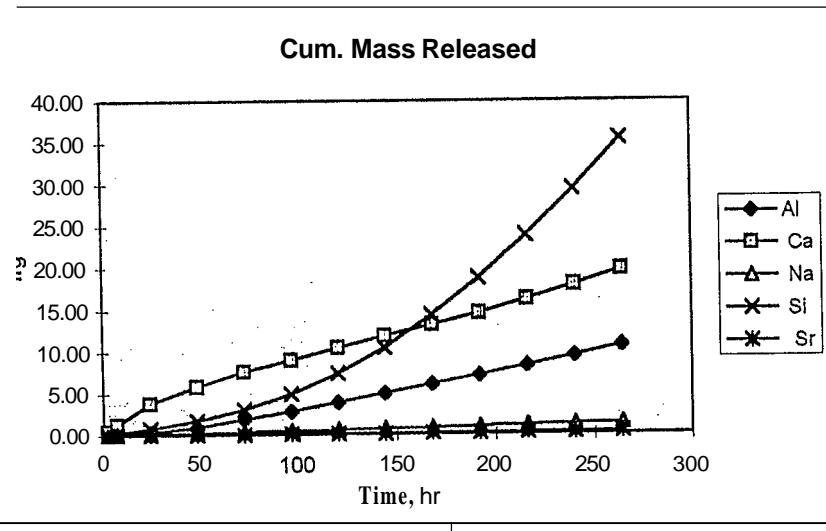


Summary

Experiment	AS001													
Temp(C)	60													
material	powder in membrane													
volume(mL)	200													
	Concentration (ppm)													
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH				
AS001-1	2	0.12	2.16	0.00	0.15	0.27	0.00	0.00	0.30	0.05				
AS001-2	7	0.25	6.14	-0.01	0.19	0.87	0.01	0.00	0.32	0.05				
AS001-3	24	1.35	18.95	-0.01	0.39	2.86	0.03	0.00	1.29	0.12				
AS001-4	48	3.11	28.91	-0.02	0.44	4.66	0.05	0.00	7.03	0.28				
AS001-5	72	4.36	37.81	-0.03	0.48	6.48	0.06	0.00	0.14	0.23				
AS001-6	96	4.91	44.99	-0.03	0.55	9.21	0.08	0.03	0.07	0.26				
AS001-7	120	5.18	52.18	-0.04	0.58	12.35	0.11	0.05	0.04	0.22				
AS001-8	144	5.36	59.22	-0.05	0.58	15.67	0.13	0.02	0.03	0.14				
AS001-9	168	5.50	65.92	-0.05	0.62	19.14	0.15	0.02	0.01	0.09				
AS001-10	192	5.61	72.84	-0.06	0.66	22.32	0.17	0.02	0.04	0.08				
AS001-11	216	5.73	80.86	-0.07	0.68	25.12	0.19	0.01	0.02	0.07				
AS001-12	240	5.86	89.51	-0.07	0.70	27.76	0.21	0.03	0.03	0.06				
AS001-13	264	6.01	98.47	-0.08	0.74	30.49	0.22	0.02	0.02	0.06				
	Cumulative Mass Released (mg)													
time(hrs)	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr	
AS001-1	2	0.02	0.43	0.03	0.05	0.00	0.00	0.06	0.01	8.8E-05	3.4E-04	1.0E-02	1.2E-04	3.0E-07
AS001-2	7	0.07	1.23	0.07	0.23	0.00	0.00	0.12	0.02	2.6E-04	1.3E-03	2.3E-02	5.1E-04	1.3E-06
AS001-3	24	0.34	3.79	0.15	0.80	0.01	0.00	0.38	0.04	1.2E-03	4.3E-03	4.8E-02	1.8E-03	4.9E-06
AS001-4	48	0.97	5.78	0.23	1.73	0.02	0.00	1.79	0.10	3.4E-03	8.9E-03	7.8E-02	3.8E-03	1.1E-05
AS001-5	72	1.84	7.56	0.33	3.03	0.03	0.00	1.82	0.15	6.5E-03	1.5E-02	1.1E-01	6.7E-03	1.9E-05
AS001-6	96	2.82	9.00	0.44	4.87	0.05	0.01	1.83	0.20	1.0E-02	2.2E-02	1.5E-01	1.1E-02	3.0E-05
AS001-7	120	3.86	10.44	0.55	7.34	0.07	0.02	1.84	0.24	1.4E-02	3.0E-02	1.8E-01	1.6E-02	4.4E-05
AS001-8	144	4.93	11.84	0.67	10.48	0.09	0.02	1.84	0.27	1.7E-02	4.0E-02	2.2E-01	2.3E-02	6.0E-05
AS001-9	168	6.03	13.18	0.79	14.30	0.12	0.02	1.85	0.29	2.1E-02	5.0E-02	2.6E-01	3.2E-02	7.9E-05
AS001-10	192	7.15	14.57	0.93	18.77	0.16	0.03	1.85	0.30	2.5E-02	6.2E-02	3.1E-01	4.2E-02	1.0E-04
AS001-11	216	8.30	16.17	1.06	23.79	0.19	0.03	1.86	0.32	2.9E-02	7.4E-02	3.5E-01	5.3E-02	1.2E-04
AS001-12	240	9.47	17.90	1.20	29.34	0.24	0.03	1.86	0.33	3.4E-02	8.8E-02	4.0E-01	6.5E-02	1.5E-04
AS001-13	264	10.67	19.69	1.35	35.44	0.28	0.04	1.87	0.34	3.8E-02	1.0E-01	4.5E-01	7.8E-02	1.8E-04

Summary

Experiment AS001

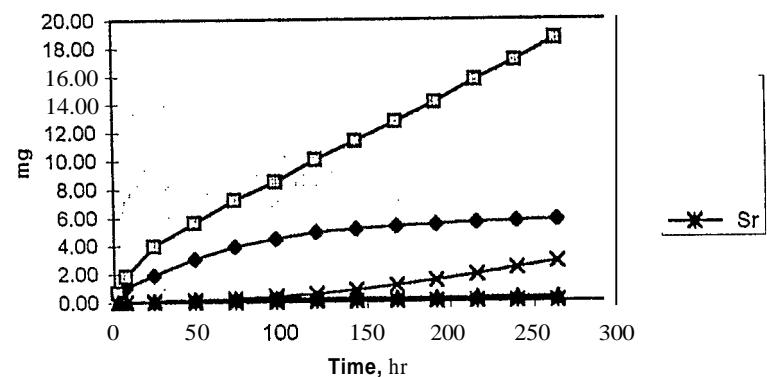
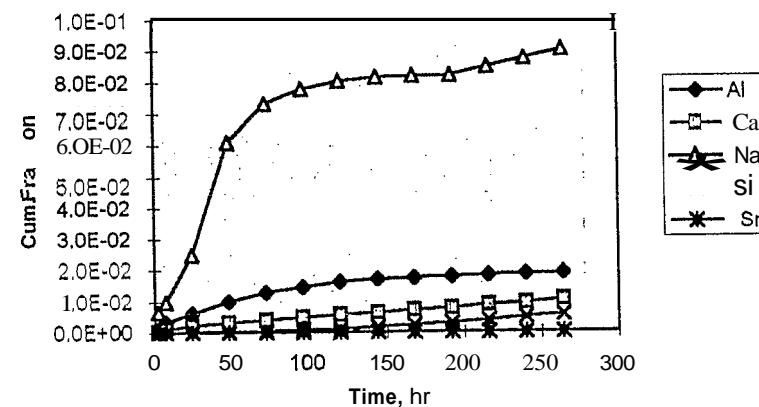


Experiment AS002
Temp(C) 60
material powder in membrane
volume(mL) 200

Concentration (ppm)											
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH	
AS002-1	2	1.958	3.38	-0.00517	0.1005	0.01249	0.002991	n.a.	n.a.	9.58	
AS002-2	7	3.192	5.763	-0.01326	0.04459	0.04261	0.005768	n.a.	n.a.	9.93	
AS002-3	24	4.417	10.62	-0.01255	0.2281	0.3143	0.01897	n.a.	n.a.	10.25	
AS002-4	48	5.766	8.335	-0.00815	0.5392	0.3825	0.03178	n.a.	n.a.	10.35	
AS002-5	72	4.241	7.887	-0.0086	0.1842	0.4945	0.02745	n.a.	n.a.	10.35	
AS002-6	96	2.684	6.541	-0.00585	0.06669	0.6566	0.0237	n.a.	n.a.	10.38	
AS002-7	120	2.41	7.739	-0.01021	0.03706	0.8366	0.01882	n.a.	n.a.	10.26	
AS002-8	144	1.178	6.633	-0.00929	0.01955	1.316	0.01691	n.a.	n.a.	10.42	
AS002-9	168	0.8959	6.708	-0.01126	0.006186	1.714	0.01775	n.a.	n.a.	10.20	
AS002-10	192	0.6685	6.968	-0.00599	0.004493	1.791	0.01648	n.a.	n.a.	11.14	
AS002-11	216	0.5937	7.883	-0.01543	0.03843	2.024	0.01594	n.a.	n.a.	11.16	
AS002-12	240	0.4324	6.992	-0.01853	0.04067	2.392	0.01794	n.a.	n.a.	11.20	
AS002-13	264	0.4418	7.742	-0.0146	0.04185	2.239	0.01403	n.a.	n.a.	11.02	

time(hrs)	Cumulative Mass Released (mg)							Cumulative Fractional Releases (cations)					
	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr
AS001-1	2	0.39	0.68	0.02	0.00	0.00	n.a.	n.a.	1.3E-03	3.7E-04	6.7E-03	4.9E-06	3.6E-07
AS001-2	7	1.03	1.83	0.03	0.01	0.00	n.a.	n.a.	3.4E-03	1.0E-03	9.7E-03	2.1E-05	1.0E-06
AS001-3	24	1.93	3.95	0.07	0.07	0.01	n.a.	n.a.	6.3E-03	2.2E-03	2.5E-02	1.4E-04	3.3E-06
AS001-4	48	3.08	5.62	0.18	0.15	0.01	n.a.	n.a.	1.0E-02	3.1E-03	6.1E-02	2.9E-04	7.1E-06
AS001-5	72	3.93	7.20	0.22	0.25	0.02	n.a.	n.a.	1.3E-02	4.0E-03	7.3E-02	4.8E-04	1.0E-05
AS001-6	96	4.46	8.51	0.23	0.38	0.02	n.a.	n.a.	1.5E-02	4.7E-03	7.8E-02	7.4E-04	1.3E-05
AS001-7	120	4.95	10.05	0.24	0.55	0.03	n.a.	n.a.	1.6E-02	5.5E-03	8.0E-02	1.1E-03	1.6E-05
AS001-8	144	5.18	11.38	0.24	0.81	0.03	n.a.	n.a.	1.7E-02	6.3E-03	8.1E-02	1.6E-03	1.8E-05
AS001-9	168	5.36	12.12	0.25	1.15	0.03	n.a.	n.a.	1.7E-02	7.0E-03	8.2E-02	2.2E-03	2.0E-05
AS001-10	192	5.50	14.11	0.25	1.51	0.04	n.a.	n.a.	1.8E-02	7.8E-03	8.2E-02	2.9E-03	2.2E-05
AS001-11	216	5.61	15.69	0.25	1.92	0.04	n.a.	n.a.	1.8E-02	8.6E-03	8.5E-02	3.7E-03	2.4E-05
AS001-12	240	5.70	17.09	0.26	2.40	0.04	n.a.	n.a.	1.9E-02	9.4E-03	8.7E-02	4.7E-03	2.6E-05
AS001-13	264	5.79	18.64	0.21	2.84	0.05	n.a.	n.a.	1.9E-02	1.0E-02	9.0E-02	5.5E-03	2.7E-05

Experiment AS002

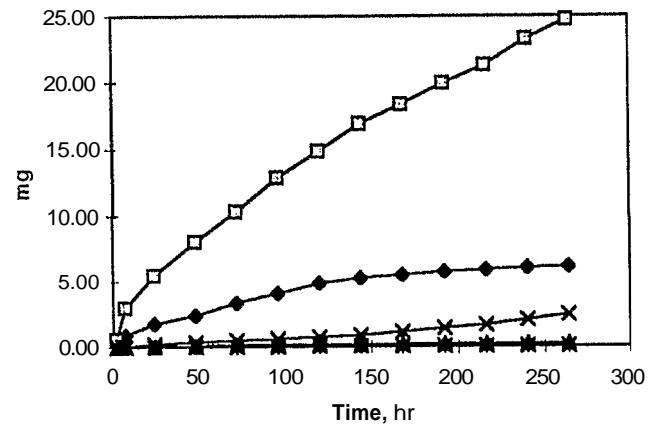
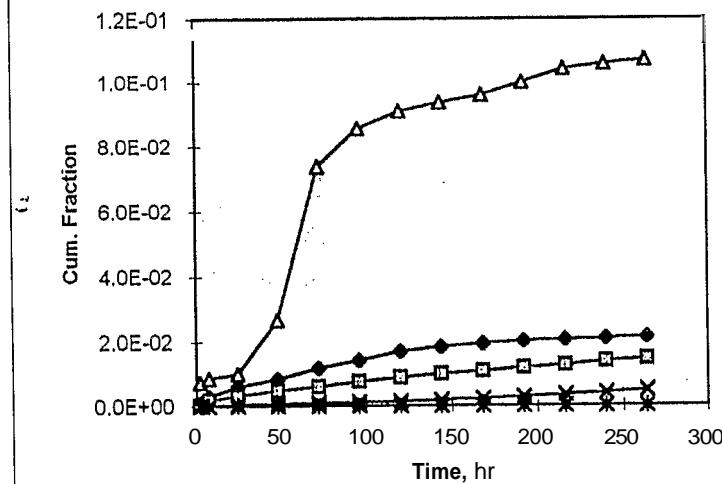
Cum. Mass Released**No Anion Data Available****Cum. Fractional Release**

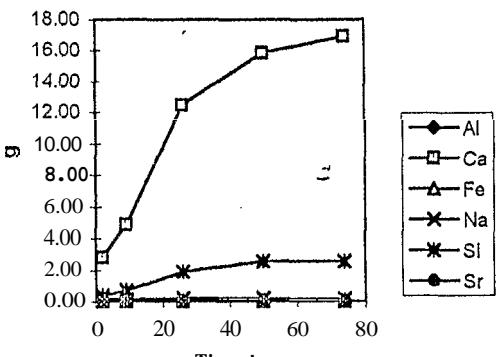
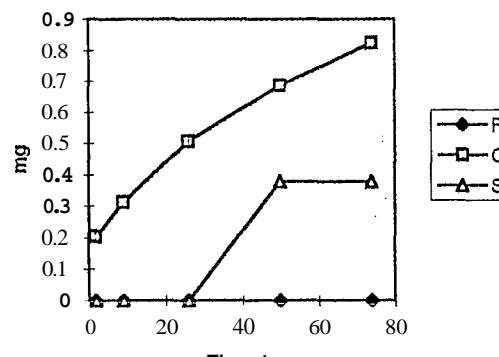
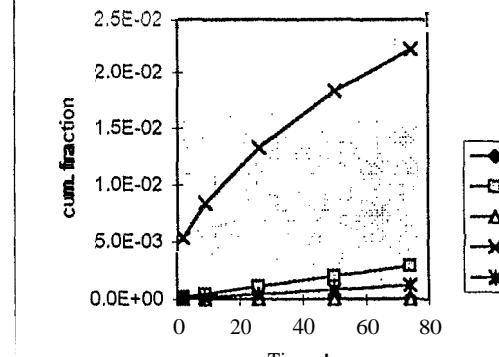
Experiment AS003
Temp(C) 60
material powder in membrane
volume(mL) 200

Concentration (ppm)										
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	pH
AS003-1	2	1.55	3.01	-0.02	0.07	0.01	0.00 n.a.	n.a.	n.a.	9.55
AS003-2	7	2.80	11.67	-0.02	0.01	0.10	0.01 n.a.	n.a.	n.a.	9.98
AS003-3	24	4.28	12.43	-0.01	0.01	0.81	0.01 n.a.	n.a.	n.a.	10.38
AS003-4	48	3.31	12.85	-0.01	0.15	0.87	0.02 n.a.	n.a.	n.a.	9.70
AS003-5	72	4.72	11.42	-0.02	0.42	0.54	0.03 n.a.	n.a.	n.a.	10.44
AS003-6	96	3.56	12.74	-0.01	0.11	0.51	0.04 n.a.	n.a.	n.a.	9.90
AS003-7	120	3.88	9.92	-0.01	0.05	0.73	0.04 n.a.	n.a.	n.a.	10.12
AS003-8	144	1.99	10.20	0.00	0.03	0.90	0.03 n.a.	n.a.	n.a.	10.00
AS003-9	168	1.34	7.22	-0.01	0.02	1.14	0.02 n.a.	n.a.	n.a.	10.10
AS003-10	192	1.16	8.08	0.00	0.04	1.29	0.02 n.a.	n.a.	n.a.	10.14
AS003-11	216	0.75	6.84	-0.01	0.04	1.45	0.02 n.a.	n.a.	n.a.	10.45
AS003-12	240	0.59	9.99	0.00	0.01	1.80	0.02 n.a.	n.a.	n.a.	10.12
AS003-13	264	0.52	7.14	0.00	0.01	1.97	0.02 n.a.	n.a.	n.a.	10.38

time(hrs)	Cumulative Mass Released (mg)					Cumulative Fractional Releases (cations)							
	Al	Ca	Na	Si	Sr	F	Cl	SO4	Al	Ca	Na	Si	Sr
AS003-1	2	0.31	0.60	0.01	0.00	0.00 n.a.	n.a.	n.a.	1.1E-03	3.6E-04	7.4E-03	2.4E-06	3.3E-07
AS003-2	7	0.87	2.94	0.02	0.02	0.00 n.a.	n.a.	n.a.	3.1E-03	1.7E-03	8.6E-03	4.4E-05	1.1E-06
AS003-3	24	1.73	5.42	0.02	0.19	0.00 n.a.	n.a.	n.a.	6.1E-03	3.2E-03	9.9E-03	3.7E-04	2.5E-06
AS003-4	48	2.39	7.99	0.05	0.36	0.01 n.a.	n.a.	n.a.	8.4E-03	4.7E-03	2.7E-02	7.2E-04	4.4E-06
AS003-5	72	3.33	10.28	0.13	0.47	0.01 n.a.	n.a.	n.a.	1.2E-02	6.1E-03	7.4E-02	9.3E-04	7.9E-06
AS003-6	96	4.05	12.82	0.15	0.57	0.02 n.a.	n.a.	n.a.	1.4E-02	7.6E-03	8.6E-02	1.1E-03	1.2E-05
AS003-7	120	4.82	14.81	0.16	0.72	0.03 n.a.	n.a.	n.a.	1.7E-02	8.7E-03	9.1E-02	1.4E-03	1.6E-05
AS003-8	144	5.22	16.85	0.17	0.90	0.04 n.a.	n.a.	n.a.	1.8E-02	9.9E-03	9.4E-02	1.8E-03	1.9E-05
AS003-9	168	5.49	18.29	0.17	1.12	0.04 n.a.	n.a.	n.a.	1.9E-02	1.1E-02	9.6E-02	2.2E-03	2.2E-05
AS003-10	192	5.72	19.91	0.18	1.38	0.04 n.a.	n.a.	n.a.	2.0E-02	1.2E-02	1.0E-01	2.8E-03	2.5E-05
AS003-11	216	5.87	21.27	0.19	1.67	0.05 n.a.	n.a.	n.a.	2.1E-02	1.3E-02	1.0E-01	3.3E-03	2.7E-05
AS003-12	240	5.99	23.27	0.19	2.03	0.05 n.a.	n.a.	n.a.	2.1E-02	1.4E-02	1.1E-01	4.1E-03	2.9E-05
AS003-13	264	6.09	24.70	0.19	2.43	0.06 n.a.	n.a.	n.a.	2.1E-02	1.5E-02	1.1E-01	4.9E-03	3.1E-05

Experiment AS003

Cum. Mass Released **^{31}t Sr****Cum. Fraction Released** **^{31}t Sr**

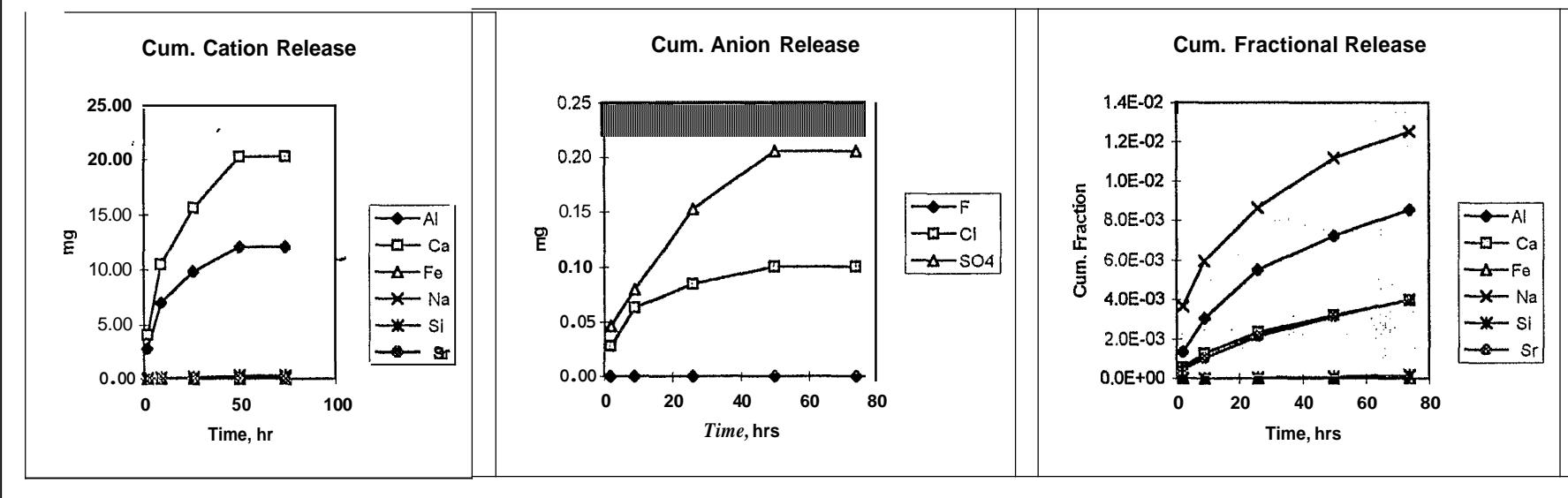
Experiment	AS001									
Temp(C)	20									
material	chunk									
Slag Leaching of AS samples ALT for 5 intervals (4 days) these are monolithic samples										
	time(hrs)	Al	Ca	Fe	Na	Si	Sr	I	Cl	SO4
AS001-1	2	0.03	2.81	0.00	0.22	0.36	0.00	0.00	0.68	0.00
A:3001-2	9	0.00	4.87	0.00	0.13	0.69	0.01	0.00	0.37	0.00
A:5001-3	26	0.05	12.46	0.00	0.21	1.90	0.01	0.00	0.64	0.00
AS001-4	50	0.06	15.85	0.00	0.21	2.54	0.02	0.00	0.60	1.26
AS001-5	74	0.05	16.91	0.00	0.16	2.56	0.02	0.00	0.45	0.00
	Cumulative Fractional Releases (cations)									
	time(hrs)	Al	Cn	Fe	Na	Si	Sr	F	Cl	SO4
AS001-1	2	0.01	0.84	0.00	0.07	0.11	0.00	0	0.203806	0
AS001-2	9	0.01	2.30	0.00	0.11	0.31	0.00	0	0.313548	0
AS001-3	26	0.02	6.04	0.00	0.17	0.88	0.01	0	0.506381	0
AS001-4	50	0.04	10.80	0.00	0.23	1.65	0.01	0	0.686671	0.37848
AS001-5	74	0.06	15.87	0.00	0.28	2.42	0.02	0	0.823065	0.37848
	Cum. Fractional Release									
	Time, hr	mg	Time, hr							
Cum. Cation Release										
										
Cum. Anion Release										
										
Cum. Fractional Release										
										

Summary

Experiment AS002
 Temp(C) 20
 Material chunk

	time(hrs)	ppm Al	ppm Ca	ppm Fe	ppm Na	ppm Si	ppm Sr	ppm F	ppm Cl	ppm SO4
S002-1	2	7.56	11.00	0.07	0.12	0.04	0.01	0.00	0.13	0.66
S002-2	9	9.50	13.72	0.03	0.07	0.03	0.01	0.00	0.09	0.15
S002-3	26	13.77	21.26	0.01	0.09	0.10	0.02	0.00	0.11	0.11
S002-4	50	9.63	16.98	0.01	0.08	0.25	0.02	0.00	0.07	0.24
S002-5	74	7.44	15.59	0.01	0.04	0.50	0.02	0.00	0.05	0.18

time(hrs)	Cumulative Fractional Releases (cations)														
	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4	Al	Ca	Fe	Na	Si	Sr
S002-1	2	2.85	4.12	0.01	0.02	0.01	0.00	0.03	0.05	1.3E-03	5.6E-04	7.3E-06	3.7E-03	6.5E-06	4.4E
S002-2	9	6.98	10.49	0.01	0.05	0.04	0.01	0.00	0.08	3.0E-03	1.3E-03	1.1E-05	6.0E-03	1.3E-05	1.0E
S002-3	26	9.87	15.59	0.02	0.07	0.12	0.01	0.00	0.15	5.5E-03	2.3E-03	1.2E-05	8.6E-03	3.1E-05	2.1E
S002-4	50	12.10	20.27	0.02	0.09	0.27	0.02	0.00	0.21	7.2E-03	3.2E-03	1.3E-05	1.1E-02	7.6E-05	3.1E
S002-5	74	12.10	20.27	0.02	0.09	0.27	0.02	0.00	0.21	8.5E-03	4.0E-03	1.5E-05	1.3E-02	1.7E-04	4.0E



Summary

Experiment	AS003																			
np	20																			
material	chunk																			
Concentration																				
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4											
AS chunk	1.92	12.14	18.13	0.8255	0.1128	0.4229	0.0157	0	0.1568	0.6419										
AS chunk	8.88	13.57	17.28	0.0191	0.0601	0.0483	0.0158	0	0.1411	0.5091										
AS chunk	25.92	25.54	31.36	0.0191	0.0817	0.1131	0.0415	0	0.1829	0.5533										
chunl.	49.92	20.81	29.54	0.0162	0.0848	0.2006	0.0391	0	0.0888	0.3099										
chunl.	73.92	17.31	26.54	0.0179	0.0377	0.3605	0.0365	0	0.0575	0.1107										
Cumulative Mass Release(mg)																				
time(hrs)	Al	Ca	Fe	Na	Si	Sr	F	Cl	SO4											
AS chunk	1.92	4.071	5.184	0.0057	0.018	0.0145	0.0047	0	0.0423	0.1527										
chunk	8.88	11.733	14.592	0.0115	0.0425	0.0484	0.0172	0	0.0972	0.3187										
AS chunk	25.92	17.976	23.454	0.0163	0.068	0.1086	0.0289	0	0.1239	0.4117										
AS chunk	49.92	23.169	31.416	0.0217	0.0793	0.2167	0.0398	0	0.1411	0.4449										
AS chunl	73.92	23.169	31.416	0.0217	0.0793	0.2167	0.0398	0	0.1411	0.4449										
Cumulative Fractional Release																				
	Al	Ca	Fe	Na	Si	Sr														
AS chunk							E-05	0.0003	0.0015	2E-05										
chunk							E-05	0.0005	0.0024	2E-05										
AS chunk							E-05	0.0052	0.001	3E-05										
AS chunk							E-05	0.0014	0.0046	4E-05										
AS chunl							E-05	0.0018	0.0051	6E-05										

Cum. Cation Releases

Time (hr)	Al (mg)	Ca (mg)	Fe (mg)	Na (mg)	Si (mg)	Sr (mg)
0	4.071	5.184	0.0057	0.018	0.0145	0.0047
1.92	12.14	18.13	0.8255	0.1128	0.4229	0.0157
8.88	23.169	31.416	0.0217	0.0793	0.2167	0.0398
25.92	31.416	31.416	0.0217	0.0793	0.2167	0.0398
49.92	31.416	31.416	0.0217	0.0793	0.2167	0.0398
73.92	31.416	31.416	0.0217	0.0793	0.2167	0.0398

Cum. Anion Release

Time (hr)	F (mg)	Cl (mg)	SO4 (mg)
0	0.00	0.00	0.00
1.92	0.00	0.00	0.00
8.88	0.00	0.00	0.00
25.92	0.00	0.00	0.00
49.92	0.00	0.00	0.00
73.92	0.00	0.00	0.00

Cum. Fractional Release

Time (hr)	F (Cum. Fraction)	Cl (Cum. Fraction)	SO4 (Cum. Fraction)	Sr (Cum. Fraction)
0	0.000	0.000	0.000	0.000
1.92	0.000	0.000	0.000	0.000
8.88	0.000	0.000	0.000	0.000
25.92	0.000	0.000	0.000	0.000
49.92	0.000	0.000	0.000	0.000
73.92	0.000	0.000	0.000	0.000

APPENDIX B

Table B-1 Concentrations (ppm) of Elements in Leachate from Column E-1

	Al	Ca	Fe	Na	Sr ppm	Si
E1 Col 1	125.800	262.300	0.006	68.340	6.509	0.209
E1 Col 2	102.100	212.600	-0.001	44.140	3.398	0.110
E1 Col 3	109.700	213.200	0.001	36.610	2.007	0.087
E1 Col 4	120.000	249.300	0.005	37.980	1.506	0.125
E1 Col 5	14.640	200.300	0.004	29.260	1.155	0.090
E1 Co16	18.090	202.600	0.008	15.690	0.686	0.052
E1 Col 7	29.680	189.400	0.013	17.230	0.713	0.078
E1 Col 8	11.740	210.800	0.010	10.220	0.899	0.150
E1 Co19	10.110	210.800	0.001	7.073	1.006	0.094
E1 Col 10	7.001	188.300	0.008	4.340	1.025	0.146
E1 Col 11	9.049	155.600	0.000	3.057	0.736	0.414
E1 Col 12	6.156	123.400	-0.013	2.320	0.586	1.076
E1 Col13	4.972	105.500	0.003	1.883	0.477	1.545
E1 Col 14	3.876	80.130	0.005	1.555	0.435	1.652
E1 Col 15	3.250	51.940	0.004	1.540	0.233	1.873
E1 Col 16	3.366	78.440	0.000	1.415	0.279	2.161
E1 Col17	2.829	113.700	-0.004	1.187	0.344	2.510
E1 Col 18	2.624	81.160	-0.003	1.282	0.280	2.199
E1 Col 19	2.549	95.540	0.004	1.152	0.274	2.460
E1 Col 20	2.411	108.600	-0.001	0.942	0.267	2.699
E1 Col21	3.401	121.400	0.007	0.927	0.254	2.545
E1 Col 22	0.195	4.516	4.366	0.192	---	2.609

Table B-2 Concentrations (ppm) of Elements in Leachate from Column Q-BOP

	Effluent (g)	Days	Al ppm	Ca ppm	Fe ppm	Na ppm	Si ppm	Sr ppm
QBOP A Col 1	71.43	1.08	0.149	694.50	-0.002	42.88	0.161	4.646
QBOP A Col 2	155.32	2.35	0.115	705.50	0.031	1.91	0.031	1.415
QBOP A Co13	239.75	3.63	0.029	700.00	0.071	1.03	0.015	0.952
QBOP A Co14	328.21	4.97	0.161	669.10	0.296	0.80	0.013	0.827
QBOP A Co15	413.90	6.27	0.021	728.50	0.229	0.71	0.019	0.777
QBOP A Co16	492.72	7.47	0.108	625.50	0.370	0.54	0.008	0.644
QBOP A Co17	575.67	8.72	0.053	682.10	0.205	0.40	0.006	0.542
QBOP A Col 8	657.37	9.96	0.060	639.30	0.158	0.40	0.008	0.555
QBOP A Col 9	741.51	11.24	0.049	642.30	0.020	0.39	0.007	0.589
QBOP A Col 10	824.00	12.48	-0.041	633.90	0.020	0.32	0.010	0.471
QBOP A Col 11	912.46	13.83	0.091	748.60	-0.098	0.34	0.012	0.456
QBOP A Col 12	989.17	14.99	0.184	704.80	-0.034	0.32	0.009	0.524
QBOP A Col13	1067.43	16.17	0.129	765.10	-0.157	0.32	0.010	0.485
QBOP A Col14	1151.18	17.44	0.192	805.30	-0.138	0.32	0.012	0.488
QBOP A Col 15	1235.15	18.71	0.113	783.90	-0.171	0.27	0.016	0.447
QBOP A Col16	1324.00	20.06	0.130	683.80	-0.164	0.31	0.009	0.459
QBOP A Col17	1411.05	21.38	0.163	792.70	-0.170	0.33	0.017	0.513
QBOP A Col 18	1496.05	22.67	0.282	727.90	-0.171	0.28	0.016	0.462
QBOP A Col 19	1581.85	23.97	0.076	847.40	-0.164	0.26	0.003	0.418
QBOP A Col 20	1668.41	25.28	0.076	737.90	-0.170	0.30	0.013	0.471

QBOP A Col 21	1757.11	26.62	0.069	638.60	-0.008	0.34	0.031	0.454
QBOP A Col 22	1980.55	30.01	0.193	688.40	-0.013	0.33	0.036	0.467
QBOP A Col 23	2184.21	33.09	0.155	719.90	-0.001	0.29	0.038	0.438
QBOP A Col 24	2459.18	37.26	0.115	755.80	-0.013	0.33	0.040	0.396
QBOP A Col 25	2680.45	40.61	0.168	689.70	-0.013	0.29	0.028	0.412
QBOP A Col 26	2883.53	43.69	0.211	670.90	-0.014	0.33	0.014	0.387
QBOP A Col 27	2985.51	45.24	0.203	665.20	-0.004	0.29	0.030	0.381
QBOP A Col 28	3189.25	48.32	0.244	696.50	-0.006	0.27	0.047	0.301
QBOP A Col 29	3385.20	51.29	0.291	657.20	0.009	0.29	0.046	0.364
QBOP A Col 30	3486.16	52.82	0.123	711.80	0.001	0.36	0.038	0.378
QBOP A Col 31	3743.24	56.72	0.135	725.20	-0.002	0.34	0.066	0.327
QBOP A Col 32	3951.32	59.87	0.188	749.60	-0.013	0.31	0.047	0.309
QBOP A Col 33	4157.22	62.99	0.227	755.50	0.007	0.30	0.050	0.329.
QBOP A Col 34	4375.71	66.30	0.194	752.80	0.006	0.30	0.045	0.323
QBOP A Col 35	4467.18	67.68	0.298	712.30	-0.005	0.28	0.067	0.321
QBOP A Col 36	4692.66	71.10	0.074	677.00	-0.009	0.21	0.025	0.348
QBOP A Col 37	4858.78	73.62	0.080	637.00	-0.010	0.23	0.028	0.324
QBOP A Col 38	5237.30	79.35	0.166	641.00	-0.008	0.20	0.024	0.295
QBOP A Col 39	5527.30	83.75	0.153	569.00	-0.006	0.21	0.033	0.314
QBOP A Col 40	5747.66	87.09	0.156	591.00	-0.006	0.23	0.036	0.316
QBOP A Col 41	6013.66	91.12	0.136	576.00	-0.003	0.24	0.052	0.299
QBOP A Col 42	6224.03	94.30	0.084	589.00	-0.004	0.25	0.061	0.293

Table B-3 Concentrations (pprn) of Elements in Leachate from Column A§-3

	Sum	pH	Al ppm	Ca ppm				
					Fe ppm	Na ppm	Si ppm	Sr ppm
as3 Col 1	Davs	12.20	101.30	224.20	0.00	13.65	0.01	4.00
as3 Col 1	1.07	12.20	101.30	224.20				
as3 Col 2								
as3 Col 2	2.09	11.90	218.70	249.50	0.01	4.18	0.04	2.26
as3 Col 3	3.12	11.90	160.20	174.80	0.01	2.01	0.10	1.68
as3 Col 4	4.21	11.90	137.00	145.30	0.00	1.34	0.10	1.43
as3 Col 5	5.25	11.75	126.40	120.90	0.00	1.26	0.10	1.31
as3 Col 6	6.19	11.75	116.40	122.50	-0.01	1.07	0.17	1.11
as3 Col 7	7.20	11.70	92.73	101.60	0.00	1.10	0.22	1.10
as3 Col 8	8.19	11.70	83.14	91.45	0.00	1.01	0.25	1.02
as3 Col 9	9.21	11.75	74.11	97.51	-0.01	1.28	0.35	1.10
as3 Col 10	10.21	11.80	64.12	87.34	0.00	1.17	0.43	0.99
as3 Col 11	11.32	11.70	51.73	80.89	0.00	1.14	0.53	0.94
as3 Col 12	12.23	11.70	52.05	93.27	-0.01	1.12	0.62	0.87
as3 Col 13	13.17	11.60	43.38	68.51	-0.01	1.08	0.63	0.86
as3 Col 14	14.19	11.90	42.17	104.80	0.00	1.13	1.02	0.96
as3 Col 15	15.22	11.90	35.55	95.67	0.01	1.23	1.05	0.88
as3 Col 16	16.26	11.80	33.78	85.72	0.01	1.23	1.24	0.76
as3 Col 17	17.26	11.80	33.41	78.37	0.02	1.20	1.05	0.75
as3 Col 18	18.24	12.00	27.66	81.33	-0.01	1.04	1.29	0.64
as3 Col 19	19.22	11.90	24.85	62.36	0.00	0.94	1.31	0.53
as3 Col 20	20.22	11.90	23.43	76.04	0.00	0.84	1.52	0.43